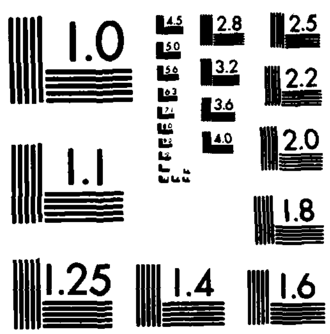
AD-A130 444 RDF (REFUSE DERIVED FUEL) UTILIZATION IN A NAVY 1/2
OIL-FIRED BOILER(U) VSE CORP OXNARD CA
G H GARDINER ET AL. JUN 83 NCEL-CR-83.033
UNCLASSIFIED N00123-82-C-0149 F/G 13/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CR 83.033

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

RDF UTILIZATION IN A NAVY OIL-FIRED BOILER

June 1983

An Investigation Conducted by
VSE CORPORATION
3410 South "A" Street
Oxnard, California 93033

N00123-82-C-0149

Approved for public release; distribution unlimited

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CR 83.033	2. GOVT ACCESSION NO. AD-A130 444	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RDF UTILIZATION IN A NAVY OIL-FIRED BOILER		5. TYPE OF REPORT & PERIOD COVERED Final Dec 1982 - May 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George H. Gardiner, P.E. Anil K. Chatterjee, P.E.		8. CONTRACT OR GRANT NUMBER(s) N00123-82-C-0149
9. PERFORMING ORGANIZATION NAME AND ADDRESS VSE Corporation 3410 South "A" Street Oxnard, CA 93033		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Y0817-006-01-211 63721
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Civil Engineering Laboratory Port Hueneme, CA 93043		12. REPORT DATE June 1983
		13. NUMBER OF PAGES 126
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Facilities Engineering Command 200 Stovall Street Alexandria, VA 22332		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

refuse derived fuel; RDF combustion; RDF oil; RDF economics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the economics of co-firing refuse derived fuel (RDF) in an fuel oil fired boiler. The report specifies the type of RDF required; the cost and type of modifications to the oil boiler; and the price which can be paid for RDF based on boiler size and RDF feedrate. Life cycle economic procedures are used to develop breakeven graphs of RDF price versus boiler size.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

This report is the second in a series of three reports on Refuse Dervied Fuel (RDF) use in Navy steam boilers. The reports examined the economical and technical aspects of burning RDF in a pulverized coal, a fuel oil, and a stoker coal boiler. Specific information was given on:

- the type of RDF required
- the type and cost of processing equipment necessary to produce the RDF
- the type and cost of modifications to each boiler to permit RDF-fossil fuel co-firing
- an economic procedure to calculate the benefits of using RDF
- specific Naval boiler plants which are candidates for RDF-fossil fuel co-combustion

Other aspects of the solid waste to energy project being conducted by NCEL under the sponsorship of the Naval Facilities Engineering Command, include:

- a survey method for estimating solid waste generation at shore facilities
- a methodology for predicting the economic feasibility of HRI technology at Naval shore facilities
- a long-term reliability, availability, and maintainability studies of the heat recovery incinerators at NS, Mayport and NAS, Jacksonville in Florida

For information on these reports contact:

Mr. Don Brunner or Mr. Jerome Zimmerle
Code L54
Port Hueneme, CA 93043
A/V 360-4191/4116 or Comm (805) 982-4191/4116

EXECUTIVE SUMMARY

Refuse Derived Fuel (RDF) is a technically feasible alternative to fossil fuels for use in a limited number of Navy oil-fired boiler plants.

Although complete replacement of oil with RDF may be desirable, the existing Navy boilers are inadequately designed to fire 100% RDF. The principal problems are inadequate furnace volume, poor tube spacing, lack of ash handling system, poor combustion, air and flue gas flow and excessive slagging. As a result, it is recommended that any use of RDF be limited to a maximum of 20% of the energy production in any oil-fired boiler conversion consideration.

The boiler and RDF characteristics needed for converting to a co-fired RDF and oil facility are covered within this report. For the oil and RDF co-firing process, the combustion phenomenon will approximate full suspension firing. In order to achieve a full-suspension firing of fuel, the RDF will have to be refined to a fluff type fuel closely approximating RDF-3.

In order to receive, store, deliver and fire RDF in co-fired boilers, the plant must be retrofitted to provide conveyors; storage bins; prefeed mill; delivery system; feed pipes, air swept jets and dump grates in the boilers; dust collection system; and ash handling and disposal system. The overall design of this system must be carefully coordinated taking into consideration the characteristics of the fuels being fired, the condition of equipment, and the pollution control requirements for the area. A recommended plant layout is shown in figure 4-5 in this report. Detailed design requirements are contained in Section 4.

In order to provide site specific recommendations, an evaluation was made of the Navy inventory of industrial boilers by gathering information from the Navy Energy and Environmental Support Activity, engineering field divisions and field activities. This information was supplemented with field trips to 12 different boiler plant sites at 10 naval activities.

Currently the Navy has 120 industrial size boilers firing residual oil, distillate fuel, or natural gas. The two principal constraints confronting the Navy in any decision to convert boiler facilities are:

- Age of plant facilities
- Size of boiler combustion chambers

Reviewing this inventory of boilers:

- 45% are 30 years or older
- 29% have inadequate combustion chamber volume to fire solid fuels

A third factor, operations, would exclude an additional 14% of the boiler inventory from consideration for conversion to co-fired facilities. The remaining 14 boilers, or 12%, were determined to be technically sound for co-firing RDF and oil.

Life-cycle studies were conducted in six hypothetical 20-year operating situations involving plant capacities ranging from 100 MBtu per hour (two 50 MBtu per hour boilers) to 450 MBtu per hour (three 150 MBtu per hour boilers). The net present value analysis of each operation comparing co-fired to 100% oil-fired, produced financially attractive results in each case.

The 14 boilers determined to have the operating characteristics to make them technically sound, were then evaluated for economic merit. Of the 14 boilers evaluated:

- 6 represented potential candidates for conversion
- 3 would be required to be held in operational stand-by
- 5 would not be cost effective

The 5 boilers deemed not cost effective were units firing natural gas at a cost of $4.50 to $5.90 per MBtu, being evaluated to co-fire RDF ($1.50 - $3.00 per MBtu) and oil ($6.32 per MBtu).

The general conclusions address the Navy's need to plan an energy efficient replacement program for the aging inventory of boilers, vice conversion of existing assets.

As an alternative to conversion of existing assets, it is recommended that future RDF considerations be aligned towards analyzing the replacement of overaged facilities with either mass burning solid waste plants or refuse derived fuel-fired plants in lieu of conversion. Proposed tasks are outlined in this report.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

Municipal solid waste (MSW) is a potentially attractive alternate energy resource for replacement of fossil fuels (coal, oil and natural gas) consumed by Navy steam generating facilities. To date as-discarded MSW has been used successfully in dedicated mass burning incinerator-boiler systems. Within existing Navy boiler plant facilities, however, only prepared MSW in various stages of refinement (RDF-2 and RDF-3) could be used as supplemental fuel to be burned in conjunction with a fossil fuel like coal, oil, or natural gas.

Two factors that directly affect the selection of any fuel to be burned in a boiler are furnace volume and tube spacing. In general, boilers designed to burn solid fuels like coal or RDF require larger furnace volume than those designed for liquid or gaseous fuels. Boilers originally designed for solid fuels also normally have larger convection tube spacing so that the gas velocity between the tubes will be held to a moderate level.

This report deals with the requirements for burning a prepared MSW called refuse derived fuel (RDF) in an oil-fired boiler. Many successful attempts of co-firing RDF in a retrofitted coal-burning boilers have been recorded in such projects as in Ames, Iowa; Milwaukee and Madison, Wisconsin; Bridgeport, Connecticut; and Rochester, New York; however, very few case histories can be cited for RDF burning in oil-fired boilers.

2.0 OBJECTIVE AND SCOPE OF WORK

This report addresses the relative technical and economic feasibilities of co-firing a form of processed and refined MSW (RDF) with oil in retrofitted oil-fired steam generators of the Navy.

This report reviews the technology status and presents a conceptual retrofit design to co-fire oil and RDF in Navy boilers and economic evaluations

of their alternative technology. The scope of the work is as follows:

- o Evaluate the available Navy oil-fired boilers in terms of technical feasibility of co-firing oil and RDF as an energy source.
- o Specify the boiler and RDF characteristics needed for boiler conversion from oil to RDF or oil and RDF.
- o Visit 10-12 Naval boiler plant sites and examine the oil burning features with the potential for conversion to RDF firing, or co-firing with oil.
- o Conduct techno-economic evaluations of RDF firing in oil-fired boilers.
- o Develop cost curves of RDF and modifications versus oil-fired for average different size units. Determine the breakeven point for each curve.
- o Consider retrofit study on boilers having at least 50,000 lbs/hr steam capacity and above. Boilers below 50,000 lbs/hr steam capacity are generally called institutional size boilers. Such boilers are normally packaged units and could seldom be candidates for retrofitting to burn RDF.
- o Examine the technical considerations of:
  - (a) the storage and retrieval of RDF
  - (b) the mechanical alterations of the boiler that will be needed to receive and feed the RDF into the boiler
  - (c) the location of RDF injection points, in reference to oil firing
  - (d) the methods by which the ash will be handled in and out of the combustion chamber of the boiler and the boiler plant
  - (e) the type of pollution control equipment that will be required to assure compliance with applicable environmental pollution control standards of EPA

(f) the appropriate combustion control system for co-firing oil and RDF

- Prepare a list of Navy steam generators that could possibly be retrofitted for supplemental firing of RDF in a boiler originally designed for oil firing, or currently being fired with oil.

3.0 BACKGROUND

3.1 General

Attempts to burn RDF in retrofitted coal-burning boilers have produced many valuable lessons learned as a result of a variety of operating problems encountered in the field. The one principal lesson learned in a recently completed study, VSE Report, Task J3-41, Contract N00123-82-D-0149, is that a dedicated coal fuel burning boiler when retrofitted to burn RDF, can operate only when RDF is co-fired with coal and when the RDF represents no more than 50% of the energy input.[1]

A similar energy input ratio of 50:50, however, cannot be used for the oil/RDF co-firing process. The operating characteristics of the two fuels and boiler design requirements are substantially different. A dedicated oil-burning boiler or a boiler designed to burn pulverized coal is designed for high volumetric heat release rate (Btu/ft^3). Tube spacing, in general, is reduced. With the introduction of RDF, high intertubular flue gas velocity will occur and slagging will form over the tube surface, significantly decreasing the effectiveness of the the boiler.

Even with the operating experience gained in coal-RDF co-firing processes, considerably more field data is required if any projection is to be developed for RDF performance in a retrofitted boiler. The long-term erosion and corrosion effects on the boiler tubes due to high intertubular hot flue gas velocities, slagging, high ash deposits, and the flue gas ash carryover problems are still basically unknowns.

Therefore, an important consideration in any study, for a consistent and realistic assesment of the technical and economic feasibility of co-firing oil/ RDF in Navy steam generators, will be to limit the input energy provided by RDF. In this study, the ratio selected was 80% oil and 20% of appropriately refined RDF in terms of energy input. RDF input in excess of 20% could lead to excessive slagging, corrosion, and boiler wear, as well as reduced efficiency. The selection of 20% RDF as a function of energy input is in basic agreement with CEL Report CR80.005.[2]

3.2 Evaluation Methodology

3.2.1 Fuel Factors. The major technical considerations of the fuel, required to be analyzed in any plan for utilizing RDF, will include:

- o Characterization of fuels including high heat values and specific gravities for:
  - o RDF
  - o fuel oil
- o Proportioning of oil and RDF in terms of:
  - o weight basis
  - o energy basis
- o Differential ash generation rate associated with co-firing of oil and RDF, vs 100% oil
- o Differential flue gas flow rate associated with the co-firing scheme
- o Combustion characteristics of co-fired fuels in boiler

3.2.2 Plant Retrofit Factors. The major plant retrofit considerations critical to any analysis for utilizing RDF will include:

- o Ash collection, handling and removal systems
- o Air pollution control systems

- RDF receiving, handling, storage and retrieval systems
- RDF transport, distribution and control systems for the boiler(s)
- RDF feeding mechanisms
- RDF injecting point(s), with respect to existing oil burners in the boiler
- Dump grates in boilers
- Effect of boiler performance taking into consideration high moisture, high ash, high mass flow rate and low heat value resulting from co-firing RDF with oil

4.0 TECHNICAL CONSIDERATIONS

4.1 General

The selection of technical parameters becomes very critical in the development of any RDF project analysis. The applicable parameters utilized in this assessment are based on the following assumptions:

- The boiler plant shall contain more than two boilers having steaming capacity per boiler equal to or greater than 50,000 lbs/hr.
- For the case of three or four boilers in a boiler plant, no more than two boilers will be retrofitted for co-firing oil and RDF. At least one boiler shall be kept as a standby unit to meet the emergency demand of the steam plant.
- For the case of a five boiler plant or larger, three boilers may be considered for retrofit.
- For a boiler originally designed to burn coal in stoker grate, but currently being used as an oil-burning boiler, the co-firing scheme with oil and RDF will not cause derating of the boiler.

- For a boiler originally designed to burn either pulverized coal, oil, or gas, the co-firing scheme will involve derating the boiler to 70% of rated capacity level.
- Appropriately refined RDF (RDF-2 or RDF-3) will be purchased from a municipal or a privately financed resource recovery facility and delivered to the Navy boiler plant site.
- The Navy boiler plant will provide storage and retrieval facilities for the RDF at a site close to the boiler plant.
- The appropriate RDF will be received at a single station and distributed to the various boilers from a single source.
- The volumetric heat release rate for the candidate boiler shall be less than 27,000 Btu/ft^3/hr based upon the combustion intensity to solid waste heat of combustion relationship shown in figure 4-1.
- The candidate boiler/boilers shall not be over 30 years old.
- The candidate boiler/boilers shall preferably be pier or pedestal mounted.
- The candidate boiler plant shall either have installed an air pollution control equipment or possess sufficient room for the installations of such devices.
- The candidate boiler shall preferably be of hopper bottom furnace or ash pit design over which dump grates can be installed.
- The candidate boiler plant has either an existing ash collection and removal facility or has room for the installation of the system.
- The individual orientation of the boilers in the boiler plant permits RDF feed lines to be installed without excessive relocation of the existing piping systems or building support structures.

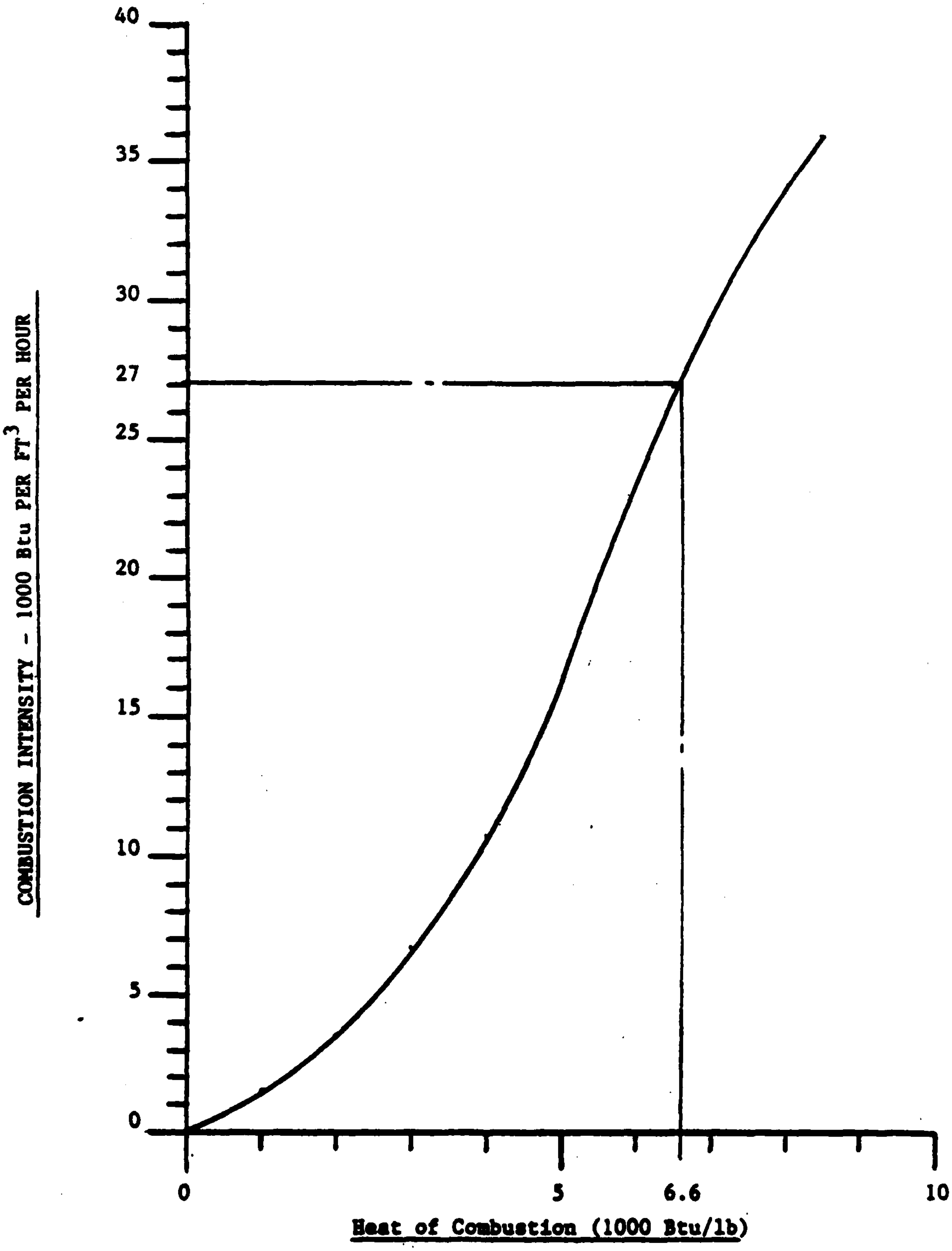


Figure 4-1. Combustion Intensity Versus Heat of Combustion of Solid Waste, Dry Basis.
Reference Data: Proceeding ASME-1968, National Incinerator Conference.

- The physical plant (steam plant) has sufficient available space for the installation and operation of the RDF receiving, storage and retrieval facilities.
- The RDF feed rate to the boiler will be constant and the oil feed rate will be variable to cope with the variations of RDF heat value and boiler plant steam load demand.

The attainable boiler efficiencies in the combustion of oil and RDF in typical Navy boilers are assumed to be as follows:

Description	Boiler Efficiency (Percent)
100 percent oil	80
80 percent oil and 20 percent RDF as a function of energy output	77
100 percent fluff RDF	66

4.2 Fuel Oil Characterization

An industrial #6 fuel oil having the following composition has been chosen as the fuel to be used in the oil/RDF co-firing scheme:(3)

Ultimate Analysis	Percent Weight
Carbon	85.6
Hydrogen	9.7
Oxygen	2.0
Sulfur	2.3
Ash	0.4
Total	100.0

Higher heat Value (HHV) - 18,300 Btu/lb

Specific gravity = 0.945 (7.87 lb./gallon)

Based on the ultimate analysis data, the stoichiometric air required for the combustion of one pound of fuel oil is 13.39 lb predicated on 1.3% moisture by dry weight per pound existing in the fuel oil (#6). Thus 1 pound of #6 fuel oil will produce 14.39 lb of combustion gases and 0.004 lb. of ash in a stoichiometric combustion process.

4.3 Refuse Derived Fuel (RDF) Specification

In the case of RDF and coal stoker grate co-firing, single stage shredding and trommeling were adequate to prepare the RDF-2 for semi-suspension firing.(1) For the oil and RDF co-firing process, the combustion phenomenon will approximate full suspension firing similar to that existing in pulverized coal burning boilers. In order to achieve a full-suspension firing of fuel, the RDF has to be prepared from a process train consisting of two stage shredding as well as two or more stages of trommelling, magnetic separation and air classification processes. The output classified as fluff RDF closely approximates RDF-3. The basic goal will be to produce a low-ash-low-moisture content RDF. In addition, the RDF should contain a minimum of metallic and inerts, i.e. glass, sand etc, to reduce slagging.

In a recent study conducted by Stone and Webster Management Consultants, Inc. for Electric Power Research Institute (EPRI), the RDF specification for co-firing with #6 fuel oil in utility boilers, was presented as:(4)

Gross heating value of RDF	=	6588 Btu/lb (dry basis)
Bulk density	=	7 lbs/cu. ft.
RDF size distribution	=	95% $\leq$ 3/16" size
Moisture	=	16% by weight
Ash	=	13% " "

Glass	=	1.2% by weight
Metals	=	0.2% " "
Sulfur	=	0.2% " "
Chloride	=	0.2% " "

The processing train is operated to produce 51.79% by weight of RDF from MSW.

The above RDF characterization was calculated from the assumed MSW composition shown in table 4-1.[4]

Table 4-1. Analysis of RDF Composition and Heat Content.

MSW Category	MSW (Wet) Composition (lb.)	RDF (Wet) Composition (lb.)	RDF Dry Composition (lb.)	Heat Content Dry Basis (Btu/lb.)	RDF Heat Content Btu
Corrugated boxes	4.96	2.86	2.40	7,841	18,818
Newspaper	15.80	9.06	7.62	8,266	62,987
Magazines and Books	4.48	3.71	3.12	7,793	24,314
Miscellaneous Paper	29.62	24.60	20.68	7,793	161,159
Plastics	3.83	1.81	1.52	13,846	21,046
Textile	0.74	0.36	0.30	8,036	2,411
Wood	0.94	0.44	0.37	8,236	3,047
Yard Waste	4.22	3.50	2.95	6,284	18,538
Food Waste	9.17	4.31	3.62	7,246	26,231
Rubber and Leather	0.72	0.33	0.28	9,049	2,534
Ferrous Metal	7.78	Trace	Trace	742	0
Aluminum	1.32	0.08	0.07	742	52
Nonferrous metals	0.65	Trace	Trace	742	0
Glass, Ceramics and Stones	14.42	0.62	0.51	84	43
Finer and Miscellaneous	1.35	0.11	0.09	84	8
Stream Total	100.00	51.79	43.53		341,188

Note: The weight of moisture in 51.79 lbs of wet RDF is 8.26 lbs or 16% by weight.

Heat Content of RDF = 341,188 ÷ 51.79 = 6588 Btu/lb for as delivered RDF

The stoichiometric standard air required for the combustion of RDF is 4.83 pounds of air per pound of RDF. Therefore, for each pound of RDF, 5.70

pounds of combustion gas and 0.13 pounds of ashes are produced at zero excess air. The volume of combustion products generated from the combustion of fuel is used to calculate the forced draft (F.D.) and induced draft (I.D.) fan capacities and to size the pollution control equipment.

4.4 Design Parameters

4.4.1 Differential Ash Generation

Fuel oil (#6) has a low ash content in the order of 0.4 percent, as compared to RDF's ash content of 13%. Standard oil-fired boilers are not normally equipped to handle the increased masses of ash produced from the combustion of even a moderate heat input from RDF.

Assume the following:

- o Energy output from the boiler is fixed = Qo
- o Boiler efficiency = Be
- o Mixture weight of RDF and oil to meet heat input rate = Wm
- o Fraction of RDF in mixture mass = Fr
- o Fraction of oil in mixture mass = 1-Fr
- o Heating value of as-received RDF = Hr = 6588 Btu/lb
- o Heating value of oil = Ho = 18,300 Btu/lb.
- o Heating value of fuel mass (RDF + oil) mixture = Hm
- o Ash content of RDF = 13%
- o Ash content of oil = 0.4%
- o Neglect the sensible heat of #6 oil in the input energy

$$Hm = Ho\,(1-Fr) + Hr\,Fr$$

$$= Ho\,[1 - Fr\,(1 - Hr/Ho)]$$

$$= Ho\,[1 - 0.64\,Fr]$$

$$Hm = 18{,}300\ \ [1.0 - 0.64\,Fr] \quad \text{.............................. Equation 1}$$

$$\text{Weight of Mixture of RDF and oil} = W_m = \frac{Q_o}{B_e \times H_m} \text{ .... Equation 2}$$

$$\text{Weight of ash produced} = W_a = \frac{Q_o}{B_e} \times \frac{0.13\ F_r + 0.004\ (1-F_r)}{18{,}300\ (1 - 0.64\ F_r)} \quad \text{Equation 3}$$

(for 0.4% oil and 13% RDF ash)

For a given sized boiler (assume 100×10^6 Btu/hr output heat rate), the weight of ash generated has been calculated from equation 3, for varying fractions of RDF in the mixture. The calculated values are noted in table 4-2 and plotted in figure 4-2.

For a given energy output per boiler, say 100×10^6 Btu/hr. from equation 2, the weight of fuel mixture (RDF + oil) can be calculated for various mass fractions of RDF in the mixture. From the mixture data, the individual weight of feed (RDF and oil) can be calculated from the equation:

Weight feed rate of RDF = Fr x Wm ....Equation 4

Weight feed rate of oil = (1-Fr) Wm ....Equation 5

From individual weight rate of feed of RDF and oil and their respective high heat values, the contribution of energy inputs can be calculated. The calculated data has been presented in table 4-2.

A breakdown between the weight rates of oil and RDF, and the total mass flow rate of mixture, for a constant 100×10^6 Btu/hr energy output from the boiler, is shown in figure 4-3.

From table 4-2, it is noted that to supply 20% of the energy input into the boiler, from RDF, approximately 41 percent of the mixture weight, or 3931 lbs/hr of RDF has to be fed into the boiler. The ash production from the RDF will be approximately 511 lbs/hr. Concurrently 5661 lbs/hr of oil input will be required. The ash content of this oil will be approximately 23 lbs/hr.

Table 4-2. Mass and Energy Fractions of Feed for an Energy Output for a 100 x 10^6 BTu/hr Boiler Operating at 100% Capacity.

Percent RDF by Weight of Mixture Fuel Feed	Total Weight Rate of Mixture (lbs/hr)	Weight Rate of RDF Feed to Boiler (lbs/hr)	Weight Rate of Oil Feed to Boiler (lbs/hr)	Percentage of Total Input Energy From RDF	Percentage of Total Input Energy From Oil	Btu Input * (Btu/hr)	Energy Output (Btu/hr)	Weight Rate of Ash Generation (lbs/hr)
0	6830.6	0	6830.6	0	100	125 x 10^6	100 x 10^6	27.3
12.8	7503.4	957.0	6546.4	5	95	126.1 x 10^6	100 x 10^6	156.6
23.6	8186.5	1930.8	6255.7	10	90	127.2 x 10^6	100 x 10^6	276.0
32.9	8887.4	2923.5	5963.9	15	85	128.4 x 10^6	100 x 10^6	403.9
41.0	9592.6	3931.4	5661.2	20	80	129.5 x 10^6	100 x 10^6	553.7
48.1	10316.6	4959.8	5356.8	25	75	130.7 x 10^6	100 x 10^6	666.2
54.3	11051.8	6006.4	5045.4	30	70	131.9 x 10^6	100 x 10^6	804.8

* Note: Thermal Efficiency of the boiler changes with the RDF and oil mix ratio.

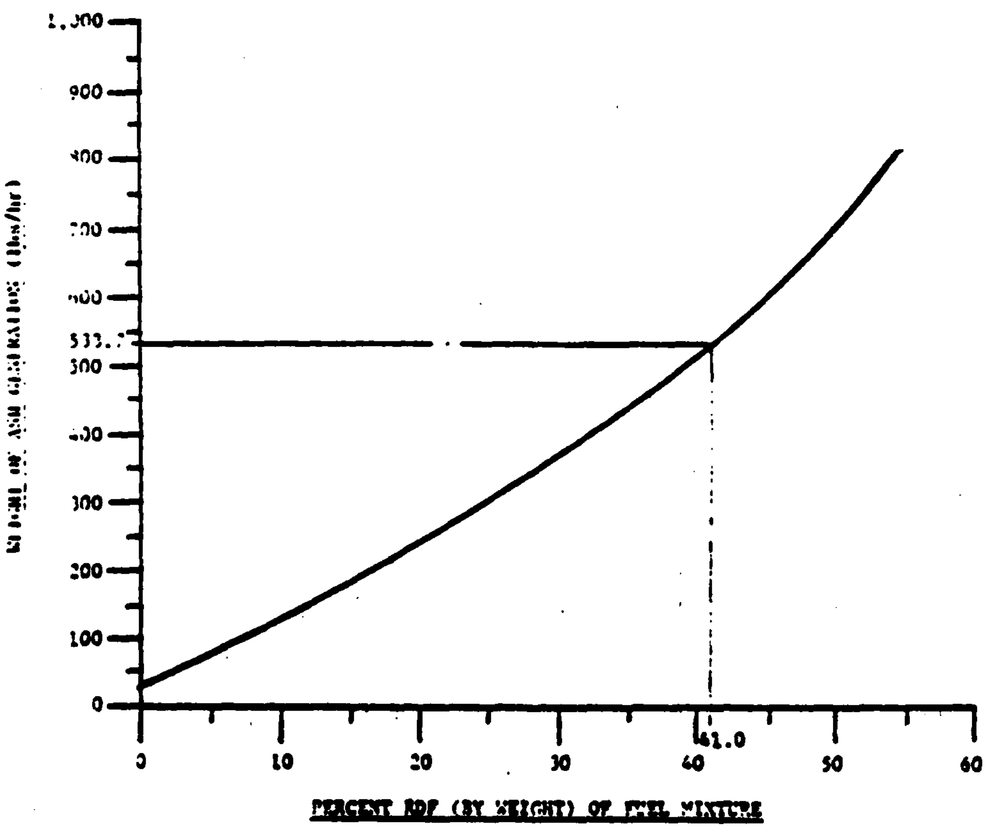


Figure 4-2. Weight of Ash Generated from Boiler Operations Producing 100 x 10^6 Btu/hr of Energy Output.

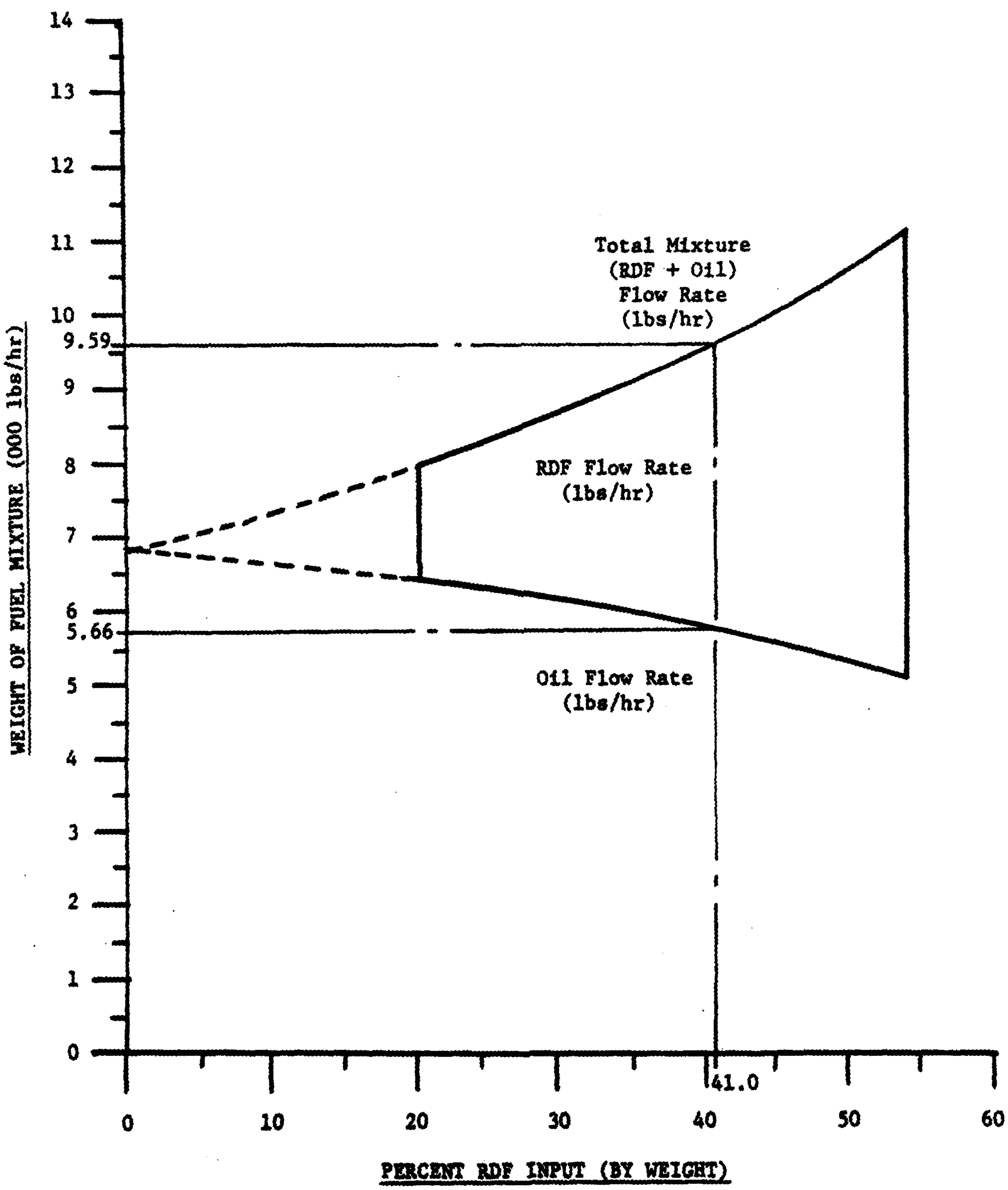


Figure 4-3. Flow Rate Mixtures for a Boiler Producing 100×10^6 Btu/hr of Energy Output

For the case of 100% oil fired boiler, over 6830 lbs/hr. of oil will be used, generating in excess of 27 lbs/hr. of ash.

For the co-firing process, total ash generation = (511 + 23) = 534 lbs/hr. Therefore, the differential ash generation rate = (534 - 27) or approximately 507 lbs/hr. This represents the increased ash generated from the combustion of RDF.

The amount of ash produced may be the limiting factor in a retrofit scheme. For technical justification of retrofit of a given capacity boiler, the maximum contribution of heat input by RDF and the consequent savings in oil use have to be evaluated in terms of differential ash production rate and the techno-economic aspects of the ash collection, handling and removal systems.

Technically, ash is a very abrasive material. The long term effect of high velocity flue gas flow through the boiler tube banks, containing high concentrations of this abrasive ash, may cause tube erosion problems. This must be considered in any retrofit considerations.

4.4.2 <u>Differential Flue Gas Volume Rate</u>

Experimental or operating field data on the amount of excess air required to support the combustion of wet RDF and oil in their various proportions are not readily available. Oil alone is normally burned at 8 to 10% excess air and RDF uses 25 to 50% excess air. But when these two fuels are co-fired, the amount of excess air needed will depend on the mechanism by which these two fuels are introduced into the furnace, the particle size of the RDF, and the moisture content.

A multifuel burner may operate with excess air of 10 - 15%. Cyclone furnaces operating on crushed coal similarly require 10 - 15% excess air. Vortex

burners using ligno-cellulosic feedstock, with a feed size of 20 mesh, will require up to 15 - 20% excess air. The RDF-3 or the fluff RDF that will be used in the co-firing process is of larger size than is normally used in Vortex burners. Therefore, it is assumed that the excess air required to burn the wet fluff RDF will be greater. Based on these factors, the excess air requirements for RDF was taken at 25%; oil at 10%.

For a 100×10^6 Btu/hr energy output in the ratio of 80% oil and 20% wet fluff RDF, the individual fuel inputs are (from table 4-2 and figure 4-3):

Fluff RDF = 3931 lbs/hr

Oil = 5661 lbs/hr

Assume that each of the above fuels is burned independent of the other. Then, total combustion products produced from the burning of these fuels can be calculated as follows:

- The stoichiometric air required for the combustion of oil = 13.39 lb per lb of oil. Assuming a 10% excess air for complete combustion of oil, the combustion products produced from burning 5661 lb/hr of oil = 5661 (1 + 13.39 x 1.1) = 89,042 lbs/hr.
- The stoichiometric air required for the combustion of fluff RDF = 4.83 lbs/# RDF. Assuming a 25% excess air for complete combustion of RDF, the combustion products produced from burning 3931 lbs/hr of fluff RDF = 3931 (1 + 4.83 x 1.25) = 27,665 lbs/hr. Assuming moisture content of the fluff RDF as 16% weight, the moisture in the flue gas = 629 lbs/hr. Total weight rate of RDF combustion products = (27,665 + 629) = 28,294 lbs/hr. Total combustion products from oil and fluff RDF is, therefore, equal to 117,336 lbs/hr.

If the entire energy output from the boiler (100×10^6 Btu/hr) would have been contributed by oil, 6831 lbs/hr of oil would have been used and combustion products resulting from the combustion of the oil would have been equal to:

6831 (1 + 13.39 x 1.1) = 107,445 lbs/hr

Therefore, by utilizing 20% of the energy input from fluff RDF, the weight increase of combustion products equals 9.2%.

For the case in which the fluff RDF and oil are fired from a single burner (Vortex type), the excess air required to sustain stable combustion of wet fluff RDF and to avoid corrosion and deposition of molten ash on the boiler tubes is assumed to be 25%. In that case, the combustion air as a function of excess air used can be calculated from the following:

$$\text{Combustion Air} = \frac{(\text{Excess air} + 100)}{100} \times (F_R \times S_A + F_O \times S_O) \qquad \text{Equation 6}$$

Where F_R = Mass fraction of RDF used in lbs/hr.

F_O = Mass fraction of oil used in lbs/hr.

S_A = Stoichiometric air need for RDF combustion

S_O = Stoichiometric air need for oil combustion

By substituting appropriate values in equation 6, the calculated values of combustion air and combustion products become 118,485 and 128,077 lbs./hr, respectively. By adding the moisture content of fluff RDF to the above combustion products, it is noted that in the multifuel burner firing process, the increase in combustion products generation is 19.2% over single fuel (oil) burning for a given heat input rate to the boiler.

4.4.3 Combustion Characteristics of Co-fired Fuel

Flame temperature in a high heat release rate furnace will decrease with the increase in RDF. Heat transfer per unit area increases with flame temperature. The rate of heat exchange (in this case the boiler tube banks) is proportional to the difference in temperature between the flame and the object.[5] When oil is fired alone stoichiometrically in the boiler, the adiabatic combustion flame temperature is over 3800°F. However, as RDF is co-fired with oil and the excess air used for the burning of the fuel mixture is increased up to 25%, the overall flame temperature will decrease. This phenomenon is illustrated in figure 4-4. The net result of this decreased flame temperature is a decrease in the steam generating capacity of the boiler.

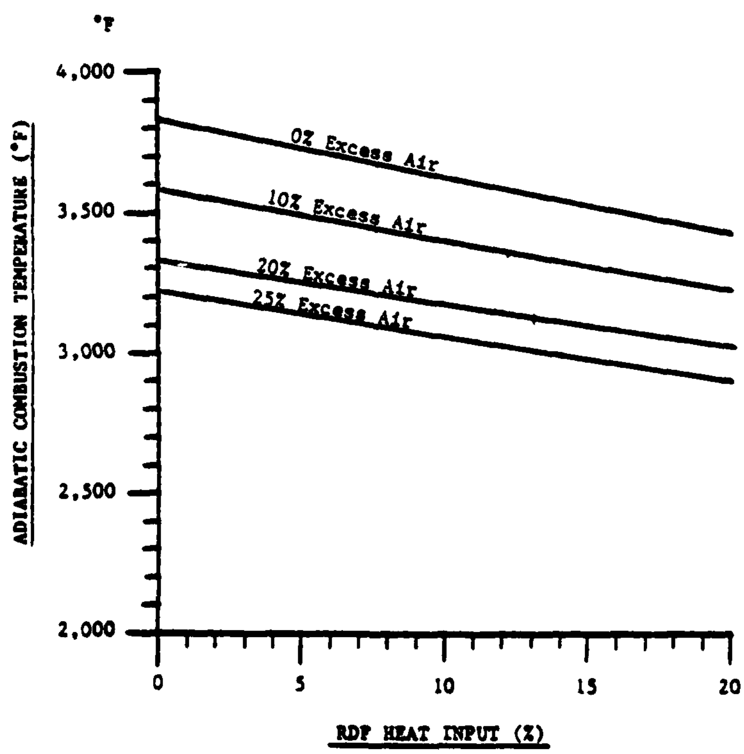


Figure 4-4. Adiabatic Combustion Temperature Versus RDF Percent Heat Input at Various Percentages of Excess Air (3)

The combustion efficiency in this multifuel firing (oil and RDF) boiler will likewise be reduced because:

- A part of the released chemical heat of the boiler will be used to supply the sensible and latent heat of evaporation of moisture in RDF.
- A part of the heat will be used to heat the excess air used in the combustion process.
- A fraction of the RDF will have incomplete combustion.
- An increase in dry flue gas heat losses will occur due to increased volume of combustion products generated in the excess air combustion process.
- A decrease in radiation heat transfer will occur due to lower adiabatic combustion flame temperature of the mixture fuel.

Based on the above phenomena, a minimum estimate of boiler efficiency drop of 3% can readily be expected when RDF percent heat input is 20% and excess air use in 25%. Maximum efficiency drops up to 10% could be realized. For a dedicated oil burning boiler, an efficiency over 85% could be achieved, although Navy boiler plant facilities frequently operate at 80%. In this study, combustion efficiency for oil/RDF co-firing process is assumed to be 77%.

4.5 Facility Retrofit Requirements

In order to accept RDF as a co-firing fuel, the following facility retrofits and additions must be provided:

- Installation and operation of a RDF receiving, storage, handling, retrieval and feeding system.
- Installation and operation of a bottom dump-grate or equivalent grate system.
- Installation and operation of an appropriate ash handling system

o Modification of burners for RDF injection.

o Upgrading or installation of an appropriate particulate emission control system.

o Upgrading of the combustion control system.

o Other plant facilities modifications to support the co-firing operation.

4.5.1 RDF Storage and Retrieval System. A typical arrangement of RDF receiving, storage and retrieval system is shown in figure 4-5. In this study, it is assumed that appropriately prepared RDF will be brought in to the Navy RDF receiving facility by the RDF vendor in self-unloading trucks. The Navy will receive the RDF and store it in Atlas or Miller-Hofft type storage and retrieval bins. The Atlas bin operates on the principle of first-in-last-out (FILO),

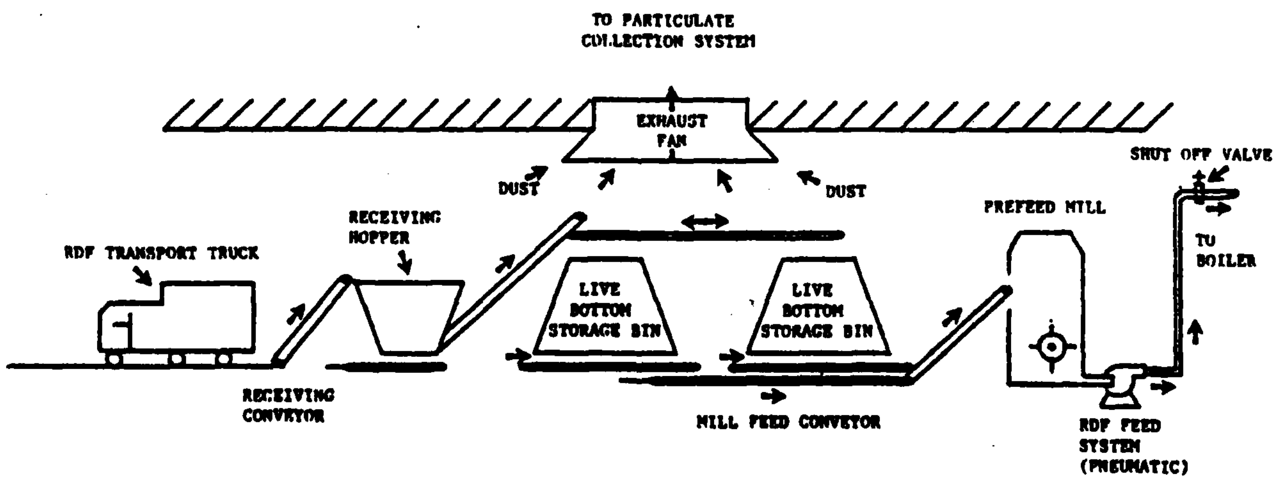


Figure 4-5. Typical Arrangement of RDF Receiving, Storage and Retrieval System[4]

while the Miller-Hofft unit operates on the principle of first-in-first-out (FIFO). Storage bins can be singular designed to feed multiple boilers or multiple providing redundancy with more than one bin.

In figure 4-5, two storage bins are shown. If one bin is out of order or is being maintained, the second bin can meet the RDF demand of the boiler. In the case of the two operating bins, one bin may be receiving RDF while the second bin can be used to feed the boilers. In this situation, two smaller bins can be purchased, instead of one large bin. Two bins offer some redundancy in storage and retrieval systems and would tend to eliminate or reduce dead spots in the storage area. These factors may tend to offset the higher capital investment cost.

The prefeed mill may be of the Doffin-Roll-bin type or equivalent design. As the RDF is stored in the bin, it compacts easily. The function of the prefeed mill is to fluff the RDF so that it can be effectively transported through the pneumatic piping system into the boiler without clogging.

If the material handling system for transporting RDF to-and-from various bins is of belt conveyer design, then the entire system should be located in a covered enclosure. To avoid dust concentration in the room, an exhaust fan blowing into the on-site particulate collection system should also be provided.

4.5.2 Ash Handling. The problem of ash removal and disposal from a co-fired RDF and oil burning boiler originally designed to burn oil becomes significant as RDF quantities are increased. The exact nature of ash distribution between flyash and bottom ash for the case involving RDF and oil-firing is difficult to estimate. The fluff RDF will primarily burn in suspension similar to pulverized coal. For dry bottom ash in a pulverized coal fired boiler, 80% of the

ash remains in the flue gases, but for slag tap (or sluice) type pulverized coal boilers only 50% of the ash goes to the flue gas. In the extreme case documented by the experience of St. Louis Union Electric Utility while co-firing coal with RDF, only 16% of the ash was found to be in the flyash.(3)

Therefore, depending upon such factors as RDF particle size, moisture content, location of RDF injection point(s) with respect to oil burners, mode of firing (multiple-fuel burner vs. single fuel burner), and furnace design, it is estimated that about 60% of the total ash in the RDF will fall to the boiler bottom ash hopper and the rest will be collected in the boiler tube banks and air heater hopper. Some ash will stick to wall tubes, some will be collected in the particulate collection equipment, and the remainder will escape to the atmosphere.(2)

In addition, the fluff RDF will contain some chunks of wood or densified combustibles. To ensure minimum carbon loss and to offer ash removal with least disturbance to the furnace environment, power operated sectional (3 or more) dump grates should be provided to the boiler furnace. The grate will be supplied with undergrate primary combustion air and overfire jets to aid in the complete burning of the carbonaceous material that failed to burn in suspension burning. The overfire jets will specifically aid in burning the volatile hydrocarbon gases. The undergrate air will cool the grate, and at the same time supply the necessary combustion air for the carbons. The ash bed will protect the grate from the radiant furnace heat.

In the situation where a boiler was originally designed for coal burning and converted to burn oil, it is possible that the boiler may have a complete traditional hydraulic or pneumatic (vacuum) ash handling system installed. In such situations, only revamping of the ash handling system may be required.

For the case where no such ash handling facility exists, a system similar to the concept shown in figure 4-6 may be installed. Figure 4-6 shows the sectional dump grate, the overfire jets, the plenum sections, and dumpster containers to receive the ashes from the ash hopper. The ash removal system described on page 66 of CEL report No. CR80.005 may be adopted.[2]

Field experience with cofiring RDF and a fossil fuel shows that the soot blowing capability of the retrofitted boiler has to be increased considerably. For boilers with superheater tube banks, highly effective soot blowing nozzles (air or steam blowing) should be installed. The furnace wall and the convective boiler tube banks should be provided with adequate soot blowing capabilities. It is important that boiler tube surfaces be kept clean so that flame cooling can be effective.

4.5.3 Emission Control System. One of the major equipment modification or addition in the oil burning boiler retrofit study is the emission control equipment. RDF contains very little sulfur, and the adiabatic flame temperature in the boiler for the co-firing of oil and RDF is lower than for oil firing alone. These two factors indicate that in the cofiring process the overall SO_X and NO_X emissions will decrease. The percentage decrease in SO_X and NO_X emissions will depend primarily upon the following:

- The sulfur content of the oil.
- The proportion of RDF in co-firing fuel.
- The excess air used in the combustion process.
- The temperature level of the combustion chamber of the boiler.

In Section 4.4.1, it was shown that for a 100×10^6 Btu/hr energy output boiler, the differential ash generation rate in the process involving 20% energy input from fluff RDF and 80% from #6 fuel oil is 507 lbs/hr. Therefore,

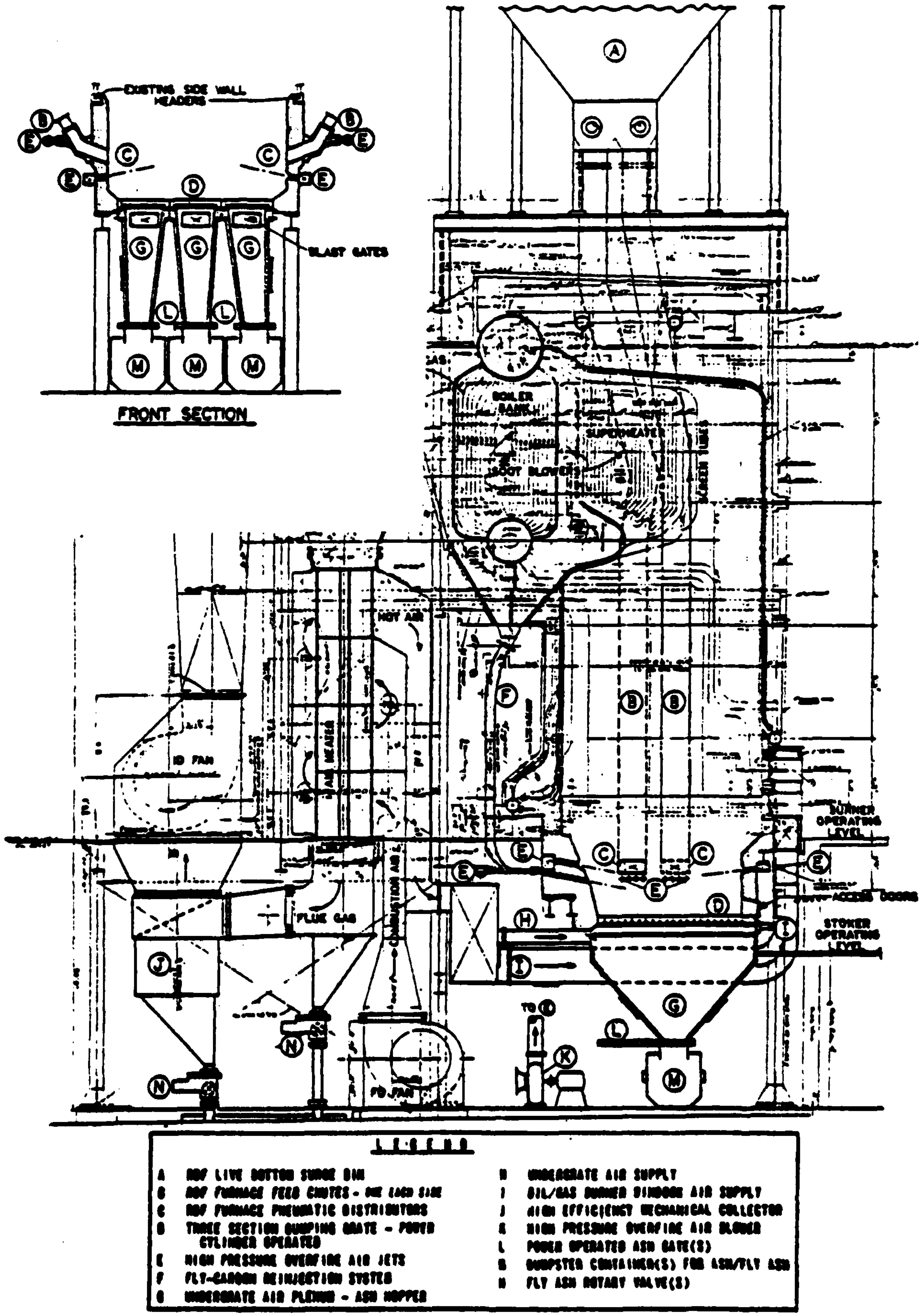


Figure 4-6. Typical Co-fired Boiler Retrofit (2)

the prime concern in the retrofit consideration is the control of particulate emission resulting from the fluff RDF combustion process.

In December 1970, the New-Source Performance Standards (NSPS) program began when the Clean Air Act (CAA) was signed into law. NSPS requires that the best emission control technology (considering cost) shall be adopted for new and modified facilities. A total of 28 Source Categories, including fossil fired steam generators and incinerators, are regulated by NSPS. Standards are currently being developed for an additional 25 Source Categories, including industrial-commercial incinerators.[6]

On September 19, 1978, the EPA proposed revised NSPS for electric utility steam generating units and promulgated final revised standards on June 11, 1979. The revised standards are much more stringent than current emission standards for power-plants. The proposed NSPS are also applicable to resource recovery units.

A comparison of the current and revised NSPS (40 CFR part 60 Subpart D, versus Subpart D2) for electric utility steam generating units for which construction or modification is commenced after September 18, 1978, is shown in table 4-3.

The exact standards required in the future for Navy solid fuel-fired boilers of the sizes evaluated in this report, have not been published. Current recommendations appear to favor the existing NSPS emission limitations shown in table 4-3. Due to the absence of firm criteria, however, this report will use the more stringent revised limitations in order to project equipment requirements.

In the case of RDF firing, the emissions of concern are particulate matter, sulfur dioxide and carbon monoxide. The air quality status analysis depends to some degree on the ambient pollutant level of the local Navy facility.

Table 4-3. Current and Revised NSPS for Fossil Fuel Fired Powerplants.[4]

Current NSPS Emission limitation (lbs/10^6Btu)	Revised NSPS Emission limitation (lbs/10^6Btu)	Removal (%)
Particulate Matter-0.10	0.03	90% solid fuel 70% liquid fuel
Opacity - (%)		
20% (40% for not more than 2 minutes)	20% (27% for not more than 6 minutes)	
Sulphur dioxide		
1.2 for solid fuel	1.2 for solid fuel	85
0.80 for liquid fuel	0.8 for liquid fuel	85
	0.2 for any fuel	no reduction
Nitrogen oxides		
0.7 for solid fuel	0.8 for ignite fuel	65
0.3 for liquid fuel	0.6 for other solid fuel	65
0.2 for gaseous fuel	0.3 for liquied fuel	30

Note: The particulate emission limits for RDF co-firing process will depend upon the heat input to the boiler. Generally, the lower the Btu/hr. input, the higher the allowable pounds per million Btu of particulate emissions.[2]

However, wherein RDF contains negligible sulfur and the fluff RDF is burned in suspension in an environmentally enclosed furnace, the chance of having any SO_2 or carbon monoxide present is minimum. Therefore, only particulate matter emission control is of importance in this case. A dry control system like bag filter, multiple cyclone (multi-clone) or electrostatic precipitator (ESP) will be quite adequate for controlling the particulate emissions.

For the case of 100% refuse incineration, the federal particulate emission standard for a maximum two-hour period is 0.08 grains per standard cubic foot corrected to 12% CO_2. However, the specific emission limitation to be applied to any supplementary RDF firing system must be treated as sensitive to the specific site condition.

The selection of any emission control equipment must consider all cost and operational aspects. Cyclone type equipment is generally used for capturing coarse particulates. Such units may not, therefore, meet the 0.03 lbs per million Btu input EPA standard. For this reason, a bag filter system or an electrostatic precipitator (ESP) will be preferred.

The bag filter system using fiberglass filter bags has initial lower capital cost than ESP but the maintenance cost of bag filter system is normally higher than ESP. A properly designed bag filtering system usually has the highest filtration efficiency. The bag filtration system designer should take into consideration the grain loading of the flue gas, the particle size distribution of the dust and the gas temperature.

The ash and combustibles that will be collected in the control equipment will need to be disposed, along with the boiler furnace bottom ash, to a land fill area.

4.5.4 Draft System Modifications. Co-firing RDF with oil will require higher excess air than firing oil alone. This differential air flow requirement has been calculated in Section 4.4.1. For supplemental firing of RDF, some additional overfire air will be required. The overfire air plus the air used for the distribution of fluff RDF across the furnace will be adequate to meet the excess air demand for the firing of the RDF.

The existing forced draft duct work should be modified to permit separate air supply to each dump grate section at the rear of the plenum-ash hopper. A separate air supply duct will also be required to the burner plenum. For the induced draft (I.D.) fan, allowance for pressure drop through the particulate collection system should be taken into account. The I.D. fan should preferably be located downstream of the particulate emission control system and should have overcapacity designed into the system.

Typical co-fire draft system modifications and the overfire jet locations are shown in figure 4-6.

4.5.5 RDF Transport and Feeding System. There are many options available for the design of RDF transport and feeding systems. Figure 4-5 shows a suggested retrieval system involving pneumatic transport of RDF. An alternate concept of RDF transport and feeding system is shown in drawing D-040-002 of NCEL Report CR80.005.(2) This plan was based on pneumatic transport of the RDF to an intermediate live bottom bin and then to feed the boiler by gravity.

Any retrieval system design must recognize that fluff RDF is a very difficult material to transport by gravity. Inherent moisture and widely distributed particle size are responsible for frequent plugging of the gravity fed transport line. In general, the chronic problem leading to the failure of the RDF supplemental fuel firing projects is normally associated with the fuel transport system design. Excessive wear of the transport line and frequent plugging are the two major cause of failure of the Chicago's Commonwealth Edison supplementary fuel firing scheme. The proper location of RDF feed line in respect to oil burners is also important. One design concept locates the air swept nozzle for the RDF above the oil burners. This concept is based on the theory that the coarse particles of RDF will burn effectively in their downward travel through the flame front envelope created by the oil burners. Another concept provides for the RDF nozzle below the oil burners. This design is based on the theory that RDF has high volatile matter content and the effective way to release the heat from these volatile hydrocarbon elements is to pass the matter through the oil burner flame envelope. The coarse particle in turn would burn on the dump grate.

A third design provides for the use of a multifuel burner, similar to pulverized coal and oil burner, using RDF in the place of pulverized coal. The secondary air of the burner will carry the RDF to the primary fuel flame front and the scroll design of the burner will offer the turbulence that is so important for the combustion of a solid fuel. Another design proposed in NCEL report CR80.005 involves the firing of RDF from two ends of the boiler.[2] In this design the solid RDF will be blown into the fire zone of the oil burner.

For the case where an existing pulverized coal-fired boiler is converted to burn fuel oil, the RDF nozzles can be located at the ports where previously pulverized burners were located. Eventually, the following aspects of the boiler will decide the RDF firing system design:

- Physical room available for the location of the RDF injection ports, air sweep piping, and overfire air jet systems.
- Design of boiler combustion area.
- Design of boiler convective tubing and waterwall tubing.
- Dedicated or converted (coal or oil) boiler.
- Dump grate location and design.

Many biomass or waste fuel burning boilers (sawdust, wood chip, bark, etc.) are sometimes designed with scroll type burners. The combustion of the RDF will be very effective in this type of burner but the fuel for such burners is generally less than 1/4" size and dry. Refinement of MSW to this category of RDF would be very expensive.

While several designs are available, field experience at Ames, Iowa indicates that better combustion characteristics are obtained by injecting RDF below the existing oil burners. Therefore, this is the type of system recommended in this study. The second choice is to use a multifuel (solid/liquid) burner and feed RDF with a secondary air stream.

4.5.6 Combustion Control System. The fundamental purpose of a combustion control system is to note automatically the change in demand for load (steam) and instantly adjust certain control variables to maintain the proper boiler working conditions (pressure and temperature) and optimum combustion conditions.[7]

For a boiler, the control variables are:

- o Steam
- o Water
- o Fuel
- o Air
- o Flue gas

Each of the above variables must be properly regulated to meet the load variation and maintain optimum combustion efficiency. The most important point in the design of a control systen is that the steam pressure has to be kept constant under all conditions of load variations by regulating the fuel, air, and feedwater flows.

For a single fossil fuel burning boiler, control devices are quite standard items. But, for a multifuel firing boiler and especially when one fuel is liquid and other is a heterogenous solid fuel having wide variations in heat release rate, the combustion control system may be quite involved due to varying characteristics of the heterogeneous solid fuel.

For the supplementary RDF firing case, it will be assumed that the weight flow rate of fluff RDF providing 20% of the energy input/output shall be kept constant and demand load variations will be met by varying the oil flow rates.

Air control devices are equally critical to allow proper propotioning of the amount of air to the amount of fuel for a given boiler load (steam). The

level of excess air is therefore an index that is commonly used to guide the boiler operation and to determine its overall performance.

Fuel-flow-air-flow, steam-flow-air-flow, and gas analysis are the three basic types of combustion guides for a boiler. Each of the above combustion guides has its field of application. The fuel-flow-air-flow ratio control proportions fuel and air continuously during severe load swings. Such type of combustion control is quite acceptable for fuels with fairly constant heating value (like oil or gas). However, such controls are in error and therefore less efficient for fuels having wide variation of heating values (like RDF). When the heating value of a fuel changes, the calibration for fuel-air relationship also changes. Therefore to maintain a constant excess air, the fuel-air ratio has to be changed frequently. This causes error.

The steam-flow-air-flow device controls air input based upon steam flow measurements. On major load changes, the steam-flow-air-flow device causes error because of the overfiring and underfiring necessary for steam pressure control. This type of control device is also affected by changing feed water or steam temperature.

A gas analyzer gives true excess air determination but it involves some delay on controlling events, since combustion has to occur before a complete sample is obtained. However, the gas analyzer is an accurate index for feedback control and is therefore a very useful tool in the combustion control process.

For a boiler originally designed to fire coal, but converted to burn oil, much of the combustion control equipment for burning coal will probably be present. In such situations the coal-burning control elements could be adjusted to accommodate supplemental RDF burning with oil.

For a dedicated oil-burning boiler when retrofitted to burn RDF and oil, additional combustion control devices will be required for the RDF portion of the fuel input regulation. An oxygen or CO_2 analyzer may also be beneficial as part of the control/monitoring devices. Likewise, some type of control or monitoring device to determine the furnace wall temperature may aid in estimating the situation where the RDF ash is in the fusion temperature range and a slagging situation may be occurring.

The control of the RDF feed rate is achieved as follows. For an Atlas RDF retrieval system, the controller regulates the volumetric discharge of RDF from the storage bin by controlling the speeds of the sweep system and the discharge conveyor(s). The controller receives a variable signal from a "Height Sensor" and a signal from the conveyor drive motor. The "Height Sensor" operates on the principle that the free end of a pivoted paddle floats on the top surface of the conveyed material (RDF) as it passes beneath the sensor. A signal is generated from the sensor which varies as the attitude of the paddle changes thereby indicating the material height. The controller determines the product of the "Height Sensor" reading and the conveyor motor speed, and since the width of the conveyor is constant, the product is proportional to the volumetric discharge rate of the conveyor. For a known density material, the volumetric discharge rate is translated to weight flow rate of RDF.[8]

5.0 FIELD SURVEY

Field visits were made to ten naval installations following extensive research of Navy boiler inventories involving liaison with the Naval Environmental and Energy Support Activity (NEESA) and contact with the different naval installations and NAVFACENGCOM Engineering Field Divisions. These visits were

coordinated to observe and evaluate boiler plant facilities at these installations for possible conversion to co-fired RDF and oil facilities. The physical plant facilities visited include:

Naval Base Norfolk, Va. - 3 sites

Naval Air Station, Oceana, Va. - 1 site

Naval Amphibious Base, Little Creek, Va. - 1 site

Fleet Combat Direction Systems Training Center-Atlantic, Dam Neck, Va. - 1 site

Naval Shipyard, Philadelphia, Pa. - 1 site

Navy Yard, Washington, D.C. - 1 site

Naval Ordnance Station, Indian Head, Md. - 1 site

MARCORPS Development and Educational Command, Quantico, Va. - 1 site

Naval Air Station, Alameda, Ca. - 1 site

Mare Island Naval Shipyard, Vallejo, Ca. - 1 site

Six other naval installations were located in the same geographical areas visited, but were excluded from the survey for the following reasons:

- Norfolk Naval Shipyard, Portsmouth, Va. - boiler plant is being replaced by an RFD-boiler plant.
- Allegany Ballistics Laboratory, Md. - inadequate boiler furnace volume.
- Naval Research Laboratory, Washington, D.C. - boilers being replaced.
- Naval Air Test Center, Patuxent River, Md. - inadequate boiler furnace volume.
- Naval Medical Center, Bethesda, Md. - inadequate boiler furnace volume.
- Naval Support Activity, Treasure Island, San Francisco, Ca. - inadequate boiler capacity.

The field data collected during the survey is presented in Annex A. The evaluation of the field data is included in sections 6, 7, and 8.

6.0 ECONOMIC EVALUATION

6.1 General

Economic evaluations are presented in this section covering both generic classes of boiler plant facilities ranging from two 50 MBtu/hr boilers to three 150 MBtu/hr boilers, and site specific boiler plant facilities considered to be technically feasible for co-firing RDF and oil. The site specific reviews will be limited to generalized evaluations based on site adapting designs developed to retrofit the generic classes of facilities.

The economic parameters surrounding the evaluations include the following:

a. The load factor per boiler was assumed to be equal to 0.72 based on 24 hour per day operations, 292 days per year, producing steam at 90% capacity. If the boiler was derated by 25%, the load factor would equal 0.54.

b. The economic life of the retrofitted boiler is 20 years.

c. The fuel mix will be maintained at 20% RDF and 80% oil as a function of energy input. The characteristics of RDF will be as specified in section 4.3.

d. Capital investment costs and O&M costs will be treated using a cost of capital of 10% and normal inflation, as outlined in the Economic Analysis Handbook, NAVFAC P-442, July 1980. The exception will be the fossil fuels (residual oil, distillate fuel, and natural gas) which will be treated as inflating at a rate 4% faster than normal inflation.

e. Plant operations were considered to be unchanged with either the introduction or variance in usage of RDF.

f. Plant maintenance is varied to account for different levels of plant and equipment upkeep and increased equipment wear.

g. Boiler efficiencies are varied to account for different ages and conditions of boilers:

	100% Oil	Co-fired	100% RDF
New Boiler	83%	80%	69%
Used Boiler	80%	77%	66%
Old Boiler	78%	75%	64%

h. RDF costs are varied to reflect potential market conditions for RDF. Typical costs being experienced in the market today vary from $25 to 35 per ton.

i. Boilers are treated as both fully rated for boilers originally designed to burn coal, and derated to 75% of capacity for boilers originally designed to burn oil, distillate fuel, or natural gas.

The life cycle cost analyses are presented in terms of:

- o Cost curves developing annual fuel cost savings (AFCS) as a function of three variables: boiler efficiency, RDF price and boiler rating factor. The annual cost factor for capital investment and O&M costs are then developed and plotted against the annual fuel cost savings curves to determine the breakeven points and annual savings or loss to be derived from co-firing RDF and oil.
- o Savings-to-investment ratios (SIR)
- o Discounted payback periods.

Annex B provides the complete economic evaluations for both the generic classes of boiler plant facilities and site specific cases.

6.2 Economic Model

The economic model is designed based on changes in conditions; i.e., the cost of the displaced fuel less the cost of the RDF must be equal to or greater than the cost of the annual capital investment recovery charge plus the cost

represented by changes in operations, maintenance, land usage, solid waste removal, administration, etc. The displaced fuel costs, less RDF costs, represent the annual fuel cost savings (AFCS).

6.3 Annual Fuel Cost Savings

The annual fuel cost savings have been derived directly as a function of the cost of displaced fuel less the cost of the replacement RDF fuel. Annex B contains the calculations, tables, and graphs depicting the annual fuel cost savings factors for the different boiler efficiencies, ratings, and RDF costs. Table 6-1 is an excerpt from Annex B for the average condition of operation; i.e., fully rated boilers operating with a co-firing efficiency of 77%.

As outlined in Table 6-1 and Annex B, major fuel cost savings could potentially be derived by converting to co-fired boilers, provided the boilers are in good operating condition and the proper modifications have been made to the boilers and plant. Savings could range from \$0.5 to 5.0 million, dependent upon the size plant.

Table 6-1. Annual Fuel Cost Savings.
(Excerpt from Table B-4, Annex B)

RDF Price		Annual Fuel Cost Savings					
		Boiler(s) Rated Output Capacity - 10^6Btu/Hour					
		100	150	200	250	300	450
(\$/Ton)	(\$/MBtu)	(\$000)	(\$000)	(\$000)	(\$000)	(\$000)	(\$000)
77% Co-firing Boiler Efficiency - No Derating							
0	0	1,177	1,766	2,354	2,943	3,531	5,297
5	0.379	1,115	1,673	2,230	2,788	3,345	5,018
10	0.759	1,053	1,579	2,106	2,632	3,159	4,738
15	1.138	991	1,486	1,982	2,477	2,972	4,459
20	1.518	929	1,393	1,857	2,321	2,786	4,179
25	1.897	866	1,299	1,733	2,166	2,599	3,899
30	2.277	804	1,206	1,608	2,011	2,413	3,619

Graphically the same data is redisplayed in figure 6-1.

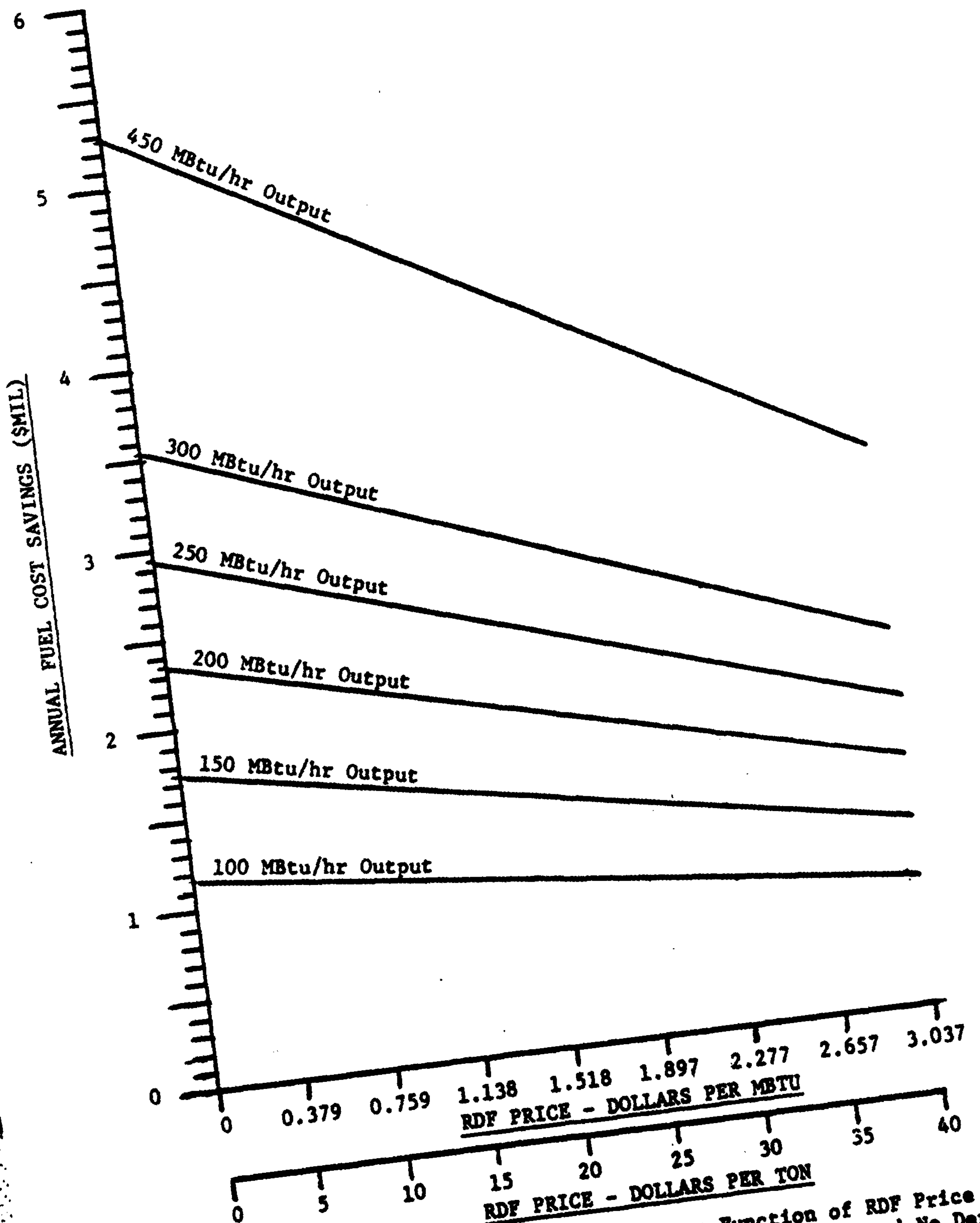


Figure 6-1. Annual Fuel Cost Savings as a Function of RDF Price and Boiler Output with a Co-Firing Efficiency of 77% and No Derating.

6.4 Design of Retrofitted Facilities

The RDF receiving, storage, and charging systems used in the analyses have been designed basically conforming with figure 4-5.

a. The RDF storage system consists of two Atlas bins providing 80 ton capacity (for two 50 MBtu/hr boilers) to 360 ton capacity (for three 150 MBtu/hr. boilers).

b. The conveyor system shall include RDF receiving conveyor, hopper bottom and lift conveyor, storage bin top conveyor and mill feed.

c. The intermediate storage bin is designed as a "live bottom" surge bin.

d. The prefeed mill will be the Doffin-Roll-bin type.

e. The pneumatic system shall include blower, valves, distribution system, 8-inch diameter pipe, structural supports, and foundation.

f. The boiler modifications have included:

- o Dump grate (3 section)
- o RDF feed pipe
- o Air swept jets
- o Grate underfire air distribution
- o Grate overfire air distribution

g. The dust collection system has been assumed to be a Pulse-Jet bag filtration system.

h. An ash handling system has been designed based upon an ash discharge system existing.

6.5 Capital Investment Costs

Using the basic design scheme outline in section 6.4, capital investment costs have been derived based upon vendor quotations and estimates provided via a telephone survey. These costs are outlined in Table 6-2.

6.6 O&M Costs

Supplemental O&M costs will be experienced annually in the operation and upkeep of the Navy boilers and RDF storage and delivery systems. These costs developed in Annex B, are restated in Table 6-3.

6.7 Annual O&M and Capital Recovery Cost Factors

The capital investment costs and O&M costs summarized in tables 6-2 and 6-3, when combined, must be equal to/or less than the AFCS if any real savings are to be realized.

Restating these costs from Annex B and applying maintenance variances, total O&M and capital recovery fees would equal:

- 100 MBtu/hr. plant (two 50 MBtu/hr. boilers)[1.]

  High Cost $583,613
  Probable Cost 508,413
  Low Cost 489,613

- 150 MBtu/hr. plant (three 50 MBtu/hr. boilers)[1.]

  High Cost $719,601
  Probable Cost 629,201
  Low Cost 606,601

- 200 MBtu/hr. plant (two 100 MBtu/hr. boilers)[1.]

  High Cost $775,144
  Probable Cost 679,944
  Low Cost 656,144

- 225 MBtu/hr. plant (three 75 MBtu/hr. boilers)[1.]

  High Cost $868,642
  Probable Cost 760,642
  Low Cost 733,643

- 300 MBtu/hr. plant (three 100 MBtu/hr. boilers)[1.]

  High Cost $997,950
  Probable Cost 877,150
  Low Cost 846,950

Note: 1. Probable cost is defined as the mostly likely cost to be incurred based on anticipated maintenance costs. High and low costs are developed by varying maintenance and repair costs.

TABLE 6-2

CAPITAL INVESTMENT COST SUMMARY

NAVY BOILER PLANT MODIFICATIONS

CAPITAL INVESTMENT COST CATEGORY	50 MBtu/hr Boilers		75 MBtu/hr Boilers		100 MBtu/hr Boilers		150 MBtu/hr Boilers	
	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers
	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)
1. Primary Storage Atlas Bins	$882	$1,036	$1,036	$1,217	$1,159	$1,386	$1,386	$1,602
2. Conveyor System Sub-Systems	60	90	75	105	85	120	105	138
3. Intermediate Storage Bin	75	90	85	110	92	130	115	153
4. Prefeed Mill Doffing Roll Bin	95	125	110	145	123	158	142	178
5. Pneumatic Delivery System	240	300	290	360	328	418	360	433
6. Boiler Mods & Equipment	300	390	345	470	386	550	401	598
7. Dust Collection System	220	280	240	320	252	353	317	380
8. Ash Handling System	30	39	35	47	39	55	40	60
9. General Mechanical	95	110	100	125	105	128	135	175
10. General Electrical	75	90	85	100	89	102	117	135
11. Sub Total	2,072	2,550	2,401	2,999	2,658	3,400	3,118	3,852
12. 10% Contingency	207	255	240	300	266	340	312	385
13. 5% Start-Up Cost	104	128	120	150	133	170	156	198
14. Sub-Total	2,383	2,933	2,761	3,449	3,057	3,910	3,586	4,435
15. Design (8%)	191	235	221	276	245	313	287	355
16. Total Costs	$2,574	$3,168	$2,982	$3,725	$ 3,302	$4,223	$3,873	$4,790

TABLE 6-3

O & M SUPPLEMENTAL COSTS

O & M COST CATEGORY	50 MBtu/hr Boilers		75 MBtu/hr Boilers		100 MBtu/hr Boilers		150 MBtu/hr Boilers	
	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers
	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)
OPERATIONS								
UTILITY TRANSFER								
Electrical	15	17	17	21	21	25	25	30
Water & Sewage	13	14	14	15	15	16	16	18
WASTE REMOVAL								
Land Fill Costs	36	53	53	80	72	106	106	159
MAINTENANCE								
Labor	52	63	60	75	66	84	77	96
Materials	42	50	48	60	53	67	62	77
Sub Total	158	197	192	251	227	298	286	380
Administrative	29	37	34	43	38	48	44	55
Sub Total	187	234	226	294	265	346	330	435
Contingency (10%)	19	23	23	29	27	35	33	44
TOTAL O & M	$206	$257	$249	$323	$292	$381	$363	$479

- o **450 MBtu/hr. plant (three 150 MBtu/hr. boilers)**

  High Cost $1,180,166
  Probable Cost 1,041,766
  Low Cost 1,007,166

6.8 Breakeven Point

The annual O&M and capital recovery cost factors have been plotted against the annual fuel cost savings for varying boiler operating conditions in figures B-1 through B-6 in Annex B.

The six different generic cases analyzed in Annex B proved to be relatively insensitive to different efficiency ratings and maintenance variances. This was principally created by the significant difference in fuel cost per MBtu; i.e.,

Residual oil = $8.84 per MBtu[1.]

Distillate Fuel = $11.76 per MBtu[1.]

Natural Gas = $6.16 - 8.26 per MBtu[1.]

Prepared RDF = $1.00 - 3.00 per MBtu

Note: 1. Residual oil, distillate fuel and natural gas prices are all increased to account for the +4% differential inflation rate.

Considering full rated boilers operating at 77% efficiency with RDF costing $30 per ton, net savings after deducting for O&M costs and capital recovery fees would still range from $275,000 per year for two 50 MBtu/hour boilers, to $2,577,000 per year for three 150 MBtu/hour boilers. The actual RDF use would have to drop to 10% or less in order to make the comparison sensitive to any of the introduced variables.

6.9 Savings-to-Investment Ratio and Discounted Payback Period

Savings-to-investment ratios (SIR) and discounted payback periods may provide a better representation of the savings potential of the different generic cases.

Assuming a normalized set of conditions with the boilers operating at full rating and 77% efficiency, average O&M costs, and RDF costs reaching $30 per ton, then:

Generic Case Total Boiler Capacity (MBtu/hr)	SIR	Discounted Payback Period
100	1.98	5.90 years
150	2.73	3.92 years
200	3.39	3.03 years
250	4.01	2.50 years
300	4.51	2.20 years
450	5.58	1.73 years

If the assumptions are correct, then each of these generic cases would be attractive investments, particularly in the plants with a retrofitted co-fired boiler capacity equal to/or greater than 200 MBtu/hr.

6.10 Site Specific Reviews

Six naval installations currently fire residual oil, distillate fuel, or natural gas and are considered to be technically suitable for converting to co-fired RDF and residual oil.

Performing a similar review of these facilities using the generic designs outlined in Annex B, indicates that significant savings would be realized in the facilities firing residual oil or distillate fuel when converting to co-fired operations; and major losses would be encountered in facilities originally firing natural gas. Again this becomes a function of the fuel operating cost.

Annex B provides more detailed analysis of each of these site specific cases. Figure 6-2 additionally provides a graphic presentation of each station assuming normalized conditions.

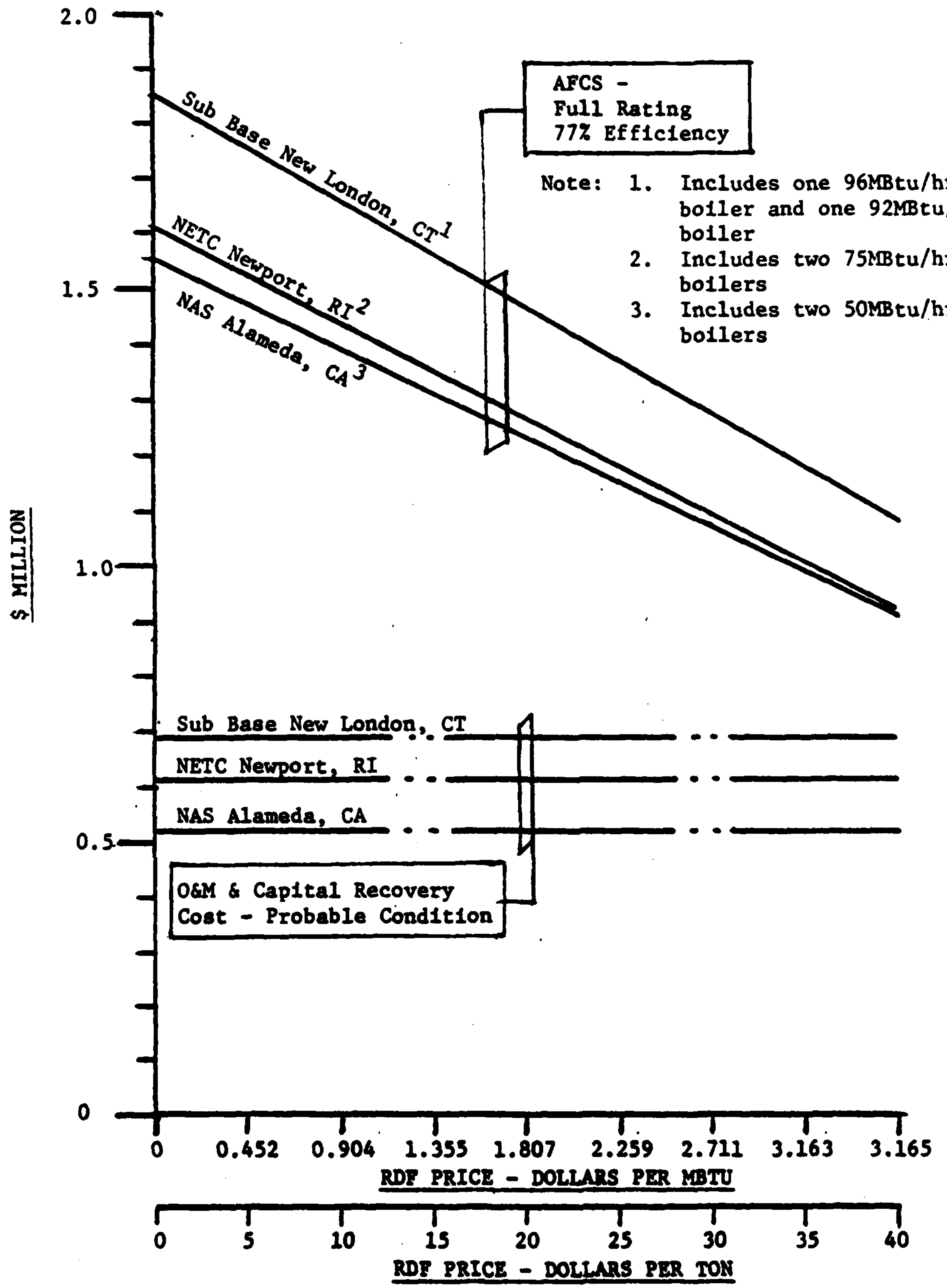


Figure 6-2. Comparison of Annual Fuel Cost Savings to O&M, RDF and Capital Recovery Costs for Navy Sub Base New London, CT; NAS Alameda, CA; and NETC Newport, RI.

6.11 Critical Cost Parameters

The economic considerations for comparing oil-fired boilers against co-fired boilers are generally insensitive to the more common variables faced in the field, due to the magnitude of the annual fuel cost savings. Likewise, the considerations surrounding a comparison of natural gas and co-fired (RDF and oil) boilers are also insensitive to normal field variances due to the magnitude of the loss.

The cost parameters that are critical to an analysis of this nature include:

- Load factor assuming 292 days of operations per year. Reducing the days of operations in half could still produce a small savings for boiler assets over 250 MBtu/hr.
- Boiler fuel mix assuming 20% RDF by energy input. Reducing the RDF to 10% for any operational reason could still produce a small savings for boiler assets over 250 MBtu/hr.
- Discount factors assuming differential inflation of +4% for oil, distillate fuel and natural gas. The effect of this differential inflation factor is to state the fuel savings at a level 40% higher than that which could have been obtained had a normal inflation factor been used.
- Derating of boilers by 20, 25, or 30% have the resultant effect on reducing the savings accordingly.
- Price of RDF. Decreasing the price of RDF from \$30 to \$20 could increase savings by as much as 17% in smaller facilities and 10% in larger facilities.

Factors that are variable but exert a smaller impact on the annual fuel cost savings include:

- o <u>Boiler efficiency</u>
- o <u>Construction costs</u>
- o <u>Increases in O&M costs</u>

7.0. NAVY BOILER PLANTS

7.1. General

An evaluation was made of the Navy inventory of boilers with 50 MBtu/hr. capacity or greater. The evaluation was based upon data provided in the Department of Energy Federal Facilities Fuel Use Act Status Report as ammended by field surveys with activities and Naval Facilities Engineering Command engineering field divisions.

7.2 Inventory

Currently there are 149 active boilers located at 35 naval installations with rated capacities of 50 MBtu/hr. or greater, categorized by primary fuel as follows:

Residual oil-fired	74 boilers
Distillate fuel-fired	10 boilers
Natural gas-fired	36 boilers
Residual oil (converted to coal)	19 boilers
Coal-fired	8 boilers
RDF-fired	2 boilers

Annex C provides a breakdown of the boiler inventory by naval installation.

7.3 Technical Evaluation

Of the 149 active boilers listed in the Navy inventory with rated capacities of 50 MBtu/hr. or greater, 30 are recommended for economic evaluation

for possible conversion to co-fired RDF and oil (or coal). The remaining 119 boilers are not considered technically suitable for co-firing RDF with a fossil fuel. The principal reason in the majority of the cases is overage of plant facilities in the case of 67 of the 119 boilers. The lack of adequate combustion chamber volume accounts for another 17 of the 119 cases; package boilers account for an additional 18 of the excluded boiler. The remaining 17 boilers considered not suitable included single unit, facilities with operational problems, and facilities where boilers were being replaced. In summary:

Category	Inventory	Technically Suitable	Technically Not Suitable
Residual oil-fired	74	6	68
Distillate fuel-fired	10	3	7
Natural gas-fired	36	5	31
Residual Oil (Converted to coal-fired)	19	11	8
Coal-fired	8	3	5
RDF-fired	2	2	0
	149	30	119

The usage of a 30-year criterion for maximum age of boiler to be considered (based on a 1983 baseline) appears well founded. Of the 67 boilers listed as overaged, 59 are World War II vintage or earlier. From the field visits made, the condition of this vintage boiler appears marginal for co-firing RDF and a fossil fuel now. If a boiler of this age was selected for conversion, approximately 3-5 more years would have to be added before the physical conversion would be realized via the Military Construction (MCON) program. Adding 20 years for the projected life of the converted boilers, the Navy plants would have to last 60 to 65 years before retirement, 20 of those years burning RDF with all the firing and slagging problems identified with RDF.

The boilers that are considered to be technically suitable to fire RDF include:

a. Oil-Fired Boilers

- Naval Education and Training Center, Newport R.I.

  Two Riley Stoker, 75 MBtu/hr. boilers

- New London Sub Base, Ct.

  One Keeler, 96 MBtu/hr. boiler

  One Babcock-Wilcox, 106 MBtu/hr. boiler (would require derating to 67% due to inadequate furnace volume)

  One Babcock-Wilcox, 99 MBtu/hr. boiler (would require derating to 72% due to inadequate furnace volume)

  One Babcock-Wilcox, 92 MBtu/hr. boiler

b. Distillate Fuel-Fired Boilers

- Naval Air Station, Alameda, Ca.

  Three Keeler, 50 MBtu/hr. boilers

c. Natural Gas-Fired Boilers

- Navy Public Works Center Great Lakes, Ill.

  One Combustion Engineering, 273 MBtu/hr. boiler

- Navy Public Works Center, Pensacola, Fla.

  Two Babcock-Wilcox, 125 MBtu/hr. boilers

- Mare Island Naval Shipyard, Vallejo, Ca.

  Two Keeler, 165 MBtu/hr. boilers

d. Coal-Fired Boilers

- Naval Ordnance Center, Indian Head, Md.

  Three Combustion Engineering, 189 MBtu/hr. boiler

- Naval Amphibious Base, Little Creek, Va.

  Three Wickes, 100 MBtu/hr. boilers

- o Puget Sound Naval Shipyard, Bremerton, Wa.

  Three New (MCON Project P500) 150 MBtu/hr. boilers

- o Bremerton SubBase, Bangor, Wa.

  Two Keeler, 60 MBtu/hr. boilers

- o Marine Corps Air Station, Cherry Pt., N.C.

  Two Keeler, 95 MBtu/hr. boilers

- o Navy Public Works Center, Norfolk, Va.

  One Riley, 220 MBtu/hr. boiler

e. RDF-Fired Boilers

- o Navy Public Works Center, NAVBASE Norfold, Va.

  Two Foster-Wheeler, 75 MBtu/hr. boilers

7.4 Economic Evaluation.

Of the 30 active boilers listed with a rated capacity of 50 MBtu/hr. or greater and having the technical characteristics considered suitable for co-firing RDF and oil, six appear to possess economic possibilities for further consideration, three would have to be retained in oil-fired standby status, five do not appear to have suitable payback potential, and 16 were coal-fired and considered to be beyond the scope of this project. In summary:

Category	Inventory	Economic Possibility	Economically Unsuitable	Other Requirement
Residual Oil-Fired	6	4	0	2[3]
Distillate Fuel-Fired	3	2	0	1[4]
Natural Gas-Fired	5	0	5	0
Res. Oil (Converted to Coal-Fired)	11[1]	-	-	-
Coal-Fired	3[1]	-	-	-

Category	Inventory	Economic Possibility	Economically Unsuitable	Other Requirement
RDF-Fired	2[2]	-	-	-
	30[1/2]	6	5	3[3/4]

Notes: 1. Not evaluated under this project.
2. Does not require evaluation; already burning solid waste.
3. Two boilers would be required to be held as fossil fuel-fired standby boilers.
4. One boiler would be required to be held in standby.

The boilers that are considered to have technical and economic possibilities for co-firing RDF and oil include:

a. Residual Oil

- Naval Education and Training Center, Newport, R.I.

  Two Riley Stoker, 75 MBtu/hr. boilers

  Note: The third backup boiler in the Codd Cove plant is inoperative and would require replacement before these boilers could be considered for conversion. The two Riley Stoker boilers cannot carry the winter demand load alone. Operating two separate plants could be very costly.

- New London Sub Base, Ct.

  One Keeler, 96 MBtu/hr. boiler

  One Babcock-Wilcox, 92 MBtu/hr. boiler

  Note: The other two candidate boilers would be required to be retained as oil-fired back-up boilers.

b. Distillated Fuel

- Naval Air Station, Alameda, Ca.

  Two Keeler, 50 MBtu/hr. boilers

  Note: The third Keeler boiler would have to be retained in standby status as fossil fuel-fired.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The basic objective of this study was to prepare a report outlining the technical and economical requirements for burning refuse derived fuel in place of oil in oil-fired boilers.

The analysis shows that oil-fired boilers could not be converted to 100% RDF-fired units due to the lack of suitable furnace volume and poor configuration of tube banks for burning solid RDF fuels. As a result, usage of RDF must be restricted to a co-firing mode of operation and then under very strict guidelines.

VSE Report task J3-41, Contract N00123-82-D-0149, recommended that the maximum level of RDF to be considered for use in a retrofitted coal-burning boiler be limited to 50% of the energy input.(1) The conversion of an oil-fired boiler to co-fire RDF and oil requires even greater restrictions. RDF in this case should be limited to 20% of the energy input to avoid excessive slagging, corrosion, and boiler wear. The selection of 20% RDF as a function of energy input is in basic agreement with CEL Report CR 80.005.(2)

As an alternative to total conversion, a co-firing mode of operation was investigated using a fuel mix of 20% RDF and 80% oil in terms of energy input. The basic results of that investigation are contained in sections 4 and 6. In general, if the boiler is in good condition, originally designed for coal, and

has adequate furnace volume, then converting to a co-fired scheme could prove to be a very attractive alternative. The boiler and RDF characteristics needed for converting to co-fired RDF and oil are covered in section 4.

The current Navy inventory of boilers that could be considered for possible conversion to co-fired RDF and oil falls generally into two classes:

- o World War II vintage boilers originally designed for coal with large furnace volumes.
- o 1960 to 1970 vintage boilers designed for oil or natural gas with limited furnace volumes.

Currently there are 120 out of 149 industrial boilers in the Navy inventory that fire residual oil, distillate fuel, or natural gas. Included within this group are:

- o 54 boilers - in excess of 30 years old.
- o 24 boilers - between 20 and 30 years old.
- o 35 boilers - either package boilers or have small combustion chambers.

These boilers account for 94.2% of the oil, distillate, and natural gas-fired boiler inventory. Boilers 20 years or older account for 65%, 30 years or older - 45%.

Technical analyses and economic evaluations conducted within this study indicated that six of the boilers currently in inventory possessed the characteristics that could make them good candidates for possible considerations for conversion to co-fired RDF and oil facilities. These included:

<u>Naval Education and Training Center, Newport, R.I.</u>

Two Riley Stoker, 75 MBtu/hr. boilers

<u>New London Sub Base, Ct.</u>

One Keeler, 96 MBtu/hr. boiler

One Babcock-Wilcox, 92 MBtu/hr. boiler

Naval Air Station, Alameda, Ca.

Two Keeler 50 MBtu/hr. boilers

The two Riley boilers at Newport, R.I. are, however, 23 years old. In addition, the third boiler in the Newport plant is inoperative. Therefore, the plant is capable of handling summer loads only. Another plant is operated during the winter season.

Site specific analyses could be conducted at the remaining stations, i.e., New London Sub Base and Naval Air Station Alameda; however:

- o The New London plant is coal capable and consideration could be given to converting this plant to either 100% coal or 50% coal, 50% RDF.
- o The Naval Air Station, Alameda will face some very stringent air pollution control criteria which may preclude any further considerations at that station for firing RDF.

8.2 Recommendations

In view of the age of the Navy boiler inventory, it is recommended that future RDF considerations be aligned towards analyzing the replacement of overaged facilities with either mass burning solid waste plants or refuse derived fuel-fired plants in lieu of conversion.

Task definitions for the engineering work could include:

Task 1: Develop a list of Navy boilers that require replacement due to age, etc. List boilers as a function of total steam production for each station. Develop steam production (load) curves for each plant and station.

Task 2: Provide a generic description and comparison of the basic technology and plant requirements to support three 100 MBtu/hour boilers for:

a. Mass burning MSW boilers

b. Dedicated RDF boilers

c. Fossil fuel-fired boilers

Task 3: Visit two or more recently designed and operating mass burning MSW sites and two sites using dedicated RDF boilers. Provide a written evaluation of strengths and weaknesses.

Task 4: Provide conceptual designs for a boiler plant housing three 100 MBtu/hour boilers and support equipment for each of the three operational concepts.

Task 5: Conduct a survey of identified Naval activities and local municipalities within 30 miles of the naval activities to determine:

a. The solid waste volume generated annually.

b. The current practices and costs for disposing of solid wastes.

c. Any use within the municipality of MSW or RDF fuels.

d. Any known potential within the municipality for development of boiler plants or processing plants.

e. Projected tipping fees that may be expected to be obtained associated with a Navy-operated MSW or RDF fuel-fired boiler plant.

Task 6: Prepare an economic analysis covering the life cycle costs associated with each of the three design options. Provide a sensitivity analysis and outline critical cost parameters.

Task 7: Provide recommendations covering potential further R&D work in the field and specific guidance covering potential site-specific surveys.

REFERENCES

1. RDF Utilization in a Navy Stoker Coal-Fired Boiler, VSE Corp., Contract No. N00123-82-D-0149, February 1983, NCEL Port Hueneme, Ca.

2. Waste Fuel Utilization in Existing Boilers on U.S. Naval Bases, CEL Report CR 80.005, Gilbert/Commonwealth, Contract No. 00123-78-C-0868, January 1980, NCEL Port Hueneme, Ca.

3. Feasibility of Burning Refuse Derive Fuel in Institutional Size Oil-Fired Boilers, US-DOE, DOE-CS-20167-03, October, NCRR, Washington DC.

4. Evaluation of Energy Recovery from Municipal Solid Waste in Oil-Fired Power Plants, EPRI CS-2274, Project 1255-90, February 1982, Stone & Webster Management Consultants, Inc.

5. Combustion - a Reference Book on Theory and Practice, 3rd edition, American Gas Association, New York, September 1967.

6. Standards of Performance for New Stationary Sources, Federal Register, August 21, 1978, Page 38, 872.

7. G. A. Gaffert, Steam Power Stations, 3rd Edition, McGraw Hill Book Co., Inc., N.Y., 1946, page 343.

8. Catalog Literature from The Atlas Systems Marx-320 series controller.

9. Navy Petroleum Office, Alexandria, Va, Message 091842Z September 1982.

10. Economic Analysis Handbook, NAVFAC P-442, July 1980.

ANNEX A

SUMMARY OF SITE VISITS

A.1 GENERAL

Site visits were made to the following field activities to evaluate boilers and prepare estimates of oil-fired boilers that might be converted to co-fired RDF and oil units:

Naval Base Norfolk, Virginia	3 sites
Naval Air Station, Oceana, Virginia	1 site
Naval Amphibious Base, Little Creek, Virginia	1 site
FCDSTC--Atlantic, Dam Neck, Virginia	1 site
Naval Shipyard, Philadelphia, Pennsylvania	1 site
Navy Yard, Washington, D. C.	1 site
Naval Ordnance Station, Indian Head, Maryland	1 site
MCDEC, Quantico, Virginia	1 site
Naval Air Station, Alameda, California	1 site
Mare Island Naval Shipyard, Vallejo, California	1 site

The trips were planned to gather the greatest amount of information on the Navy boiler inventory, at least cost.

In three cases, the stations were converting from oil-fired to coal-fired operations. These stations were still visited for the purpose of collecting the field data to be used in conjunction with an evaluation of coal-fired boilers.

A.2 NAVY FACILITY SITE VISIT DATA

Appendices I through XII provide the summary of data obtained during the site visits.

<u>APPENDICES</u>

I. Navy Facility Site Visit Data, Navy Public Works Center, Norfolk, Virginia, Building P-1
II. Navy Facility Site Visit Data, Navy Public Works Center, Norfolk, Virginia, Building SP-85
III. Navy Facility Site Visit Data, Navy Public Works Center, Norfolk, Virginia, Building NH-200
IV. Navy Facility Site Visit Data, Naval Air Station, Oceana, Virginia
V. Navy Facility Site Visit Data, Naval Amphibious Base, Little Creek Virginia
VI. Navy Facility Site Visit Data, FCDSTC, Dam Neck, Virginia
VII. Navy Facility Site Visit Data, Naval Shipyard Philadelphia, Pennsylvania
VIII. Navy Facility Site Visit Data, Washington Navy Yard, Washington, D. C.
IX. Navy Facility Site Visit Data, Naval Ordnance Station, Indian Head, Maryland
X. Navy Facility Site Visit Data, MCDEC, Quantico, Virginia
XI. Navy Facility Site Visit Data, Naval Air Station, Alameda, California
XII. Navy Facility Site Visit Data, Mare Island Naval Shipyard, Vallejo, California

APPENDIX I

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 1 December 1982
Station: Navy Public Works Center, Norfolk, Virginia--Building P-1

- Boiler Inventory: Three Riley Stoker, 75 MBtu/hour boilers (1941)
  Three Combustion Engineering 100 MBtu/hour boilers (1942)
  One Combustion Engineering 115 MBtu/hour boiler (1945)
  One Riley 200 MBtu/hour boiler (new)
- Originally designed to burn 5 coal, 3 oil
- Fuel: ·Primary 7 Res. Oil, 1 Pulv. Coal ·Secondary 4 Coal, 4 None ·Dual Res. Oil/Pulv. Coal
- Steam Production:
  - ·Annual Gross Production: 2,665,000 MBtu/year
  - ·Pressure * psig (saturated/superheated)
  - ·High Average Flow Rate 280,000 pounds/hour
  - ·Low Average Flow Rate 120,000 pounds/hour
  - ·Annual Gross Cost of Production $28,500,000
- Coal Preparation, if any: 2 pulverizers per boiler.
- Foundation: 7 pier, 1 hung ; Floor Ash Pit: 5 yes; 3 no, Ash removal door at floor level
- Ash Hopper: 5 Yes, 3 No ; Ash Handling System: 5 Yes, 3 No
  Description of Ash Handling System: Pneumatic vacuum system. Only one system with 200 MBtu/hour Riley is operative.
- APC System: 4 ESP & Multicyclone, 1 ESP & Cyclone, 3 None
- Make-up Water: 100% Condensate Return: None
- Special Features of Boiler System: The tubes in the four Comb. Eng. boilers would have to be rerouted to install dump grates. The 3 small Riley stokers all have ash removal doors at floor level.
- Boiler Plant Retrofit Conditions: Extremely congested. Considerable difficulty would be experienced attempting to route RDF lines through plant.
- Adequacy of Area Outside Plant: Marginal. Coal storage space would have to be decreased to provide RDF storage facilities.
- Other: Note: * 4 boilers--425 psig superheated at 565°F.
  2 boilers--340 psig saturated
  1 boiler--125 psig saturated

  Do not recommend conversion of seven older boilers to co-fired RDF and oil due to age and condition of units.

PREVIOUS PAGE IS BLANK

APPENDIX II

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 1 December 1982
Station: Navy Public Works Center, Norfolk, Virginia, Building SP-85

- Boiler Inventory: Two Riley Stoker, 75 MBtu/hour boilers (1943)
- Originally designed to burn pulverized coal
- Fuel:
  - Primary Diesel fuel ·Secondary Pulv. coal ·Dual
- Steam Production:
  - Annual Gross Production: 220,400 MBtu/year
  - Pressure 450 psig (saturated/~~superheated~~) 125 psig operating pressure
  - High Average Flow Rate 130,000 pounds/hour
  - Low Average Flow Rate N/A pounds/hour (interim use)
  - Annual Gross Cost of Production $3,470,000
- Coal Preparation, if any: pulverizers installed
- Foundation: Floor ; Floor Ash Pit: Yes--sloping ash bottom furnaces
- Ash Hopper: No ; Ash Handling System: Yes
  Description of Ash Handling System: Pneumatic (vacuum).
- APC System: None
- Make-up Water: 100% Condensate Return: None
- Special Features of Boiler System: Comb. chamber volume = 3,850 ft^3; HTG surface = 7,450 ft^2, WW HTG surface = 2,260 ft^2, AH HTG surface = 9,800 ft^2 Boilers designed for pulverized coal. Dump grate or stoker grate could be fitted.
- Boiler Plant Retrofit Conditions: Adequate
- Adequacy of Area Outside Plant: Adequate
- Other: Do not recommend conversion to co-fired RDF and oil due to age and condition of boilers.

APPENDIX III

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 1 December 1982
Station: Navy Public Works Center, Norfolk, Virginia, Building NH-200

- Boiler Inventory: Two Babcock Wilcox 100 MBtu/hour boilers (1900)
  One Wickes 60 MBtu/hour boiler (1900)

- Originally designed to burn coal

- Fuel:
  - Primary Residual Oil · Secondary None · Dual ______

- Steam Production:
  - Annual Gross Production: Minimum * MBtu/year
  - Pressure ______ psig (saturated/superheated)
  - High Average Flow Rate 30,000 pounds/hour
  - Low Average Flow Rate 10,000 pounds/hour
  - Annual Gross Cost of Production ______

- Coal Preparation, if any: ______

- Foundation: ______ ; Floor Ash Pit: ______

- Ash Hopper: ______ ; Ash Handling System ______
  Description of Ash Handling System: ______

- APC System: ______

- Make-up Water: ______ Condensate Return: ______

- Special Features of Boiler System: ______

- Boiler Plant Retrofit Conditions: ______

- Adequacy of Area Outside Plant: ______

- Other: Note: *The two Babcock Wilcox boilers are condemned and are no longer operated. The remaining boiler is a package boiler normally operating at 30-50% of capacity.

APPENDIX IV

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 2 December 1982
Station: Naval Air Station, Oceana, Virginia

- Boiler Inventory: Two Union Iron Works 80 MBtu/hour boilers (1954)
  One Bigelow, 80 MBtu/hour boiler (1957) *
- Originally designed to burn coal
- Fuel:
  - Primary Residual oil · Secondary Waste oil · Dual
- Steam Production:
  - Annual Gross Production: 220,000 MBtu/year
  - Pressure 90 psig (saturated/~~superheated~~)
  - High Average Flow Rate 120,000 pounds/hour (steady in winter months)
  - Low Average Flow Rate 30,000 pounds/hour
  - Annual Gross Cost of Production $3,168,000
- Coal Preparation, if any: None
- Foundation: Floor ; Floor Ash Pit: Yes
- Ash Hopper: Yes ; Ash Handling System: No
  Description of Ash Handling System: Ash hoppers only exist in basement. No removal equipment.
- APC System: None
- Make-up Water: 20% Condensate Return: 80%
- Special Features of Boiler System: Boilers have small furnace volume (2,170 ft^3). During the summer months demand load drops off substantially.
- Boiler Plant Retrofit Conditions: Adequate space exists to retrofit boilers.
- Adequacy of Area Outside Plant: Adequate
- Other: Note: * One additional small package boiler installed.

APPENDIX V

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 3 December 1983
Station: Naval Amphibious Base, Little Creek, Virginia

- Boiler Inventory: Three Wickes 100 MBtu/hour boilers (1956)

- Originally designed to burn coal

- Fuel:
  - Primary Residual oil ·Secondary Coal ·Dual Oil and Coal

- Steam Production:
  - Annual Gross Production: 740,000 MBtu/year
  - Pressure 326 Design psig (saturated/~~superheated~~) 280 psig operational
  - High Average Flow Rate 120,000 pounds/hour
  - Low Average Flow Rate 50,000 pounds/hour
  - Annual Gross Cost of Production $6,295,000

- Coal Preparation, if any: Roto grate stoker boiler. Size of coal used: top--1-1/4" to 3/4", bottom - 1/4"

- Foundation: Floor ; Floor Ash Pit: Yes

- Ash Hopper: Yes ; Ash Handling System: Yes
  Description of Ash Handling System: Each boiler has own pneumatic (vacuum) ash removal and handling system.

- APC System: One bag house for each boiler

- Make-up Water: 20% Condensate Return: In plant use of steam is returned

- Special Features of Boiler System: Exhaust gas temperature = 430°F. WWHS = 2,224 ft^2, Boiler HS = 9,611 ft^2. Has air handler and economizer.

- Boiler Plant Retrofit Conditions: Adequate

- Adequacy of Area Outside Plant: Ample space

- Other: Plant is in the process of converting to coal as the primary fuel.

APPENDIX VI

NAVY FACILITY SITE VISIT DATA

: of Plant Visit: 2 December 1982
:ion: Fleet Combat Directions System Training Center, Dam Neck, Virginia

ıiler Inventory: Two Trane-Murray 40 MBtu/hour boilers (1979)
One Keeler 45 MBtu/hour boiler (1981)

·iginally designed to burn oil

ıel:
'rimary Residual oil ·Secondary Recycled oil ·Dual

:eam Production:
ınnual Gross Production: Not available MBtu/year
'ressure 105 psig (saturated/~~superheated~~)
ligh Average Flow Rate 60,000 pounds/hour
.ow Average Flow Rate 20,000 pounds/hour
ınnual Gross Cost of Production Not available

ıal Preparation, if any: None

ıundation: Floor ; Floor Ash Pit: No

:h Hopper: No ; Ash Handling System: No
:scription of Ash Handling System: None

'C System: None

ke-up Water: 100% Condensate Return:

ecial Features of Boiler System: All package boilers. Cannot be
trcfitted for RDF.

iler Plant Retrofit Conditions: Not applicable

equacy of Area Outside Plant: Not applicable

her: Package boilers--cannot be retrofitted.

APPENDIX VII

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 15 February 1983

Station: Philadelphia Naval Shipyard, Philadelphia, Pennsylvania, Main Plant

- Boiler Inventory: Five Combustion Engineering 170 MBtu/hour boilers (2-1941; 2-1945; 1-1954)

- Originally designed to burn coal

- Fuel:
  - Primary Residual oil ·Secondary Natural gas ·Dual

- Steam Production:
  - Annual Gross Production: 2,690,000 MBtu/year
  - Pressure 900 psig (~~saturated~~/superheated) *
  - High Average Flow Rate 575,000 pounds/hour
  - Low Average Flow Rate 220,000 pounds/hour
  - Annual Gross Cost of Production $20,250,000

- Coal Preparation, if any: Has overhead coal bunker. Pulverizers have been removed.

- Foundation: Floor ; Floor Ash Pit: No

- Ash Hopper: No ; Ash Handling System: No

  Description of Ash Handling System: The boilers are mounted on concrete pads. The ash doors open at floor level. Ash has to be raked out manually.

- APC System: None

- Make-up Water: 25% Condensate Return: 75%

- Special Features of Boiler System: The boilers have preheaters but no economizers. The exhaust flue gas is over 600°F.

- Boiler Plant Retrofit Conditions: The coal bunker system could be converted to provide an RDF feed system. The installation of an ash handling and removal system would be difficult due to space limitations.

- Adequacy of Area Outside Plant: Marginal but space is available.

- Other: Note: * Boilers #187, 188, 189, and 190 @ 400 psig and superheated to 750°F. Boiler #191 @ 900 psig and superheated to 825°F.

  Do not recommend conversion to co-fired RDF and oil due to age and condition of boilers.

APPENDIX VIII

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 16 February 1983
Station: Washington Navy Yard, Washington, D. C.

- Boiler Inventory: Two Edgemoor 130 MBtu/hour boilers (1942)
  One Springfield 165 MBtu/hour boiler (1956)

- Originally designed to burn stoker-fired coal

- Fuel:
  - Primary Diesel fuel · Secondary Natural gas · Dual

- Steam Production:
  - Annual Gross Production: 580,000 MBtu/year
  - Pressure 400 psig (~~saturated~~/superheated)
  - High Average Flow Rate 140,000 pounds/hour
  - Low Average Flow Rate 60,000 pounds/hour
  - Annual Gross Cost of Production $8,700,000

- Coal Preparation, if any: None

- Foundation: Pier ; Floor Ash Pit: Yes

- Ash Hopper: No ; Ash Handling System: Yes
  Description of Ash Handling System: Sluicing system still exists. Ash hoppers have been removed and bottom plates welded on and framed to fire oil/natural gas.

- APC System: None

- Make-up Water: 100% Condensate Return:

- Special Features of Boiler System: All ash hoppers have been removed. An extensive structural frame has been placed under boilers for support. The one Springfield boiler has HTG surface = 11,400 ft^2, WW HTG surface = 4,670 ft^2, superheated to 750°F.

- Boiler Plant Retrofit Conditions: Poor

- Adequacy of Area Outside Plant: None available

- Other: The boiler plant was originally designed as power plant. Extraction steam was used for comfort heating. Currently electrical power is not produced. The superheated steam is currently desuperheated in PRV (140 psig-saturated) station and used for general heating.

APPENDIX IX

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 16 February 1983

Station: Naval Ordnance Station, Indian Head, Maryland

- Boiler Inventory: Three Combustion Engineering 189 MBtu/hour boilers (1954)
- Originally designed to burn Coal and oil
- Fuel:
  - ·Primary Pulv. coal ·Secondary Residual oil ·Dual Coal and oil
- Steam Production:
  - ·Annual Gross Production: 1,010,000 MBtu/year
  - ·Pressure 900 psig (~~saturated~~/superheated) at 825°F.
  - ·High Average Flow Rate 180,000 pounds/hour
  - ·Low Average Flow Rate 105,000 pounds/hour
  - ·Annual Gross Cost of Production $9,000,000
- Coal Preparation, if any: Two pulverizers per boiler. Use ¼" pulverized coal.
- Foundation: Pier-hung ; Floor Ash Pit: Yes
- Ash Hopper: Yes ; Ash Handling System: Yes, 5 tons/hour capacity

  Description of Ash Handling System: Fly ash reinjection system. Ash is collected first at last pass of boiler, then at air heater pass, then at mechanical cyclone. Coal w/10% ash is burned. Ash handling system is a vacuum system. The ash has to be manually removed from hoppers.
- APC System: Mechanical cyclone. Three ESPs are to be installed.
- Make-up Water: 100% Condensate Return:
- Special Features of Boiler System: Plant is designed to produce electricity (10 MW capacity) and extract steam for heat. Each boiler is fitted with dual firing coal and oil burners. New controls have been ordered. Combustion chamber volume = 9,295 ft^3, HTG surface = 11,870 ft^2, WW HTG surface = 5,105 ft^2
- Boiler Plant Retrofit Conditions: Adequate
- Adequacy of Area Outside Plant: Ample
- Other: Plant is very clean and appears to be in excellent condition even though boilers are nearly 30 years old.

APPENDIX X

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 17 February 1983
Station: MARCORPS Development and Education Command, Quantico, Virginia

- Boiler Inventory: Two Combustion Engineering 61 MBtu/hour boilers (1938)
  One Riley Stoker 67 MBtu/hour boiler (1947)
  One Riley Stoker 146 MBtu/hour boiler (1945)
  Two Henry Vogt 68 MBtu/hour boilers (1929) *

- Originally designed to burn coal

- Fuel:
  - Primary Coal
  - Secondary Residual Oil
  - Dual

- Steam Production:
  - Annual Gross Production: 1,380,000 MBtu/year
  - Pressure 120 psig (saturated/~~superheated~~)
  - High Average Flow Rate 160,000 pounds/hour
  - Low Average Flow Rate 50,000 pounds/hour
  - Annual Gross Cost of Production Not available

- Coal Preparation, if any: Two pulverizers per boiler. 3/4" to 1" coal used.

- Foundation: Floor ; Floor Ash Pit: No

- Ash Hopper: No ; Ash Handling System: Yes
  Description of Ash Handling System: Ash is manually drawn to vacuum ash handling system.

- APC System: ESP system being installed.

- Make-up Water: 50% Condensate Return: 50%

- Special Features of Boiler System: The boilers do have preheaters. Combustion chamber volumes for two CE boilers = 2,500 ft^3, one Riley Stoker = 2,700 ft^3, and one Riley Stoker = 5,600 ft^3

- Boiler Plant Retrofit Conditions: Congested area. Would be difficult to route RDF feed system.

- Adequacy of Area Outside Plant: Adequate

- Other: Note: * Two Henry Vogt boilers being removed.

  Do not recommend conversion to co-fired RDF and oil due to age and condition of boilers.

APPENDIX XI

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: January 1981
Station: Naval Air Station, Alameda, California

- Boiler Inventory: Three Keeler, 50 MBtu/hour boilers (1977)
- Originally designed to burn coal
- Fuel:
  - Primary Diesel fuel · Secondary Natural gas · Dual
- Steam Production:
  - Annual Gross Production: 700,000 MBtu/year
  - Pressure 240 psig (saturated/~~superheated~~)
  - High Average Flow Rate 75,000 pounds/hour
  - Low Average Flow Rate 50,000 pounds/hour
  - Annual Gross Cost of Production Not available
- Coal Preparation, if any: None
- Foundation: Pier ; Floor Ash Pit: No
- Ash Hopper: Yes ; Ash Handling System: No
  Description of Ash Handling System: None
- APC System: None
- Make-up Water: 100% Condensate Return:
- Special Features of Boiler System: Combustion chamber volume = 2,340 ft^3, HTG surface = 6,050 ft^2
- Boiler Plant Retrofit Conditions: Adequate
- Adequacy of Area Outside Plant: Ample
- Other: The boilers can be retrofitted to burn RDF and coal or oil. However, the permit to burn coal and/or RDF in California will be very difficult to obtain.

APPENDIX XII

NAVY FACILITY SITE VISIT DATA

Date of Plant Visit: 8 February 1983
Station: Mare Island Naval Ship Yard, Vallejo, California

- Boiler Inventory: Two Keeler 165 MBtu/hour boilers (1980)
  One Combustion Engineering 150 MBtu/hour boiler (1975) *
  One Edgemoor Iron Works 165 MBtu/hour boiler (1934) *
- Originally designed to burn (Keelers) coal and RDF; (CE) oil or natural gas
- Fuel:
  - Primary Natural gas · Secondary Diesel fuel · Dual
- Steam Production:
  - Annual Gross Production: 710,000 MBtu/year
  - Pressure 600 psig (~~saturated~~/superheated) at 750°F.
  - High Average Flow Rate 130,000 pounds/hour
  - Low Average Flow Rate 40,000 pounds/hour
  - Annual Gross Cost of Production $6,200,000
- Coal Preparation, if any: None
- Foundation: Pier ; Floor Ash Pit: Yes
- Ash Hopper: Yes ; Ash Handling System: No
  Description of Ash Handling System: None
- APC System: None
- Make-up Water: 40% Condensate Return: 60%
- Special Features of Boiler System: The two Keeler boilers are the only units considered for possible conversion. The combustion chamber volume for the Keeler boilers = 8,025 ft^3. The boilers are equipped with Detroit rotograte travelling stoker units.
- Boiler Plant Retrofit Conditions: Adequate
- Adequacy of Area Outside Plant: Ample
- Other: Note: * The Combustion Engineering boiler is a package boiler. The Edgemoor Iron Works boiler is being removed.

ANNEX B

ECONOMIC ANALYSIS

B.1 GENERAL

The applicable economic parameters used in this study are based on the following assumptions:

- o The life cycle cost estimate shall be prepared in accordance with the Economic Analysis Handbook, NAVFAC P-442, July 1980.
- o Stream factor for each retrofitted boiler is 0.80 or an operation of 292 days per year at 24 hours per day. Fossil fuel fired boilers will assume to be operated 305 days per year.
- o Economic life of the retrofitted boiler is 20 years.
- o The prepared RDF will have a minimum heating value of 6588 Btu/lb (as received) with moisture content no greater than 16 percent by weight and ash content no greater than 13% by weight. The RDF will meet the specifications established in Section 4.3.
- o The fuel mix by energy input will equal 20% RDF and 80% oil.
- o The RDF receiving, storage and charging systems are designed as shown in figure 4-5.
- o The purchase price of RDF will include delivery costs.
- o Boiler load factor of approximately 72% is assumed to be constant over the life of the project for boilers originally designed for coal and not derated; i.e., load factor =

  Rated capacity x 0.9 (average demand) x 0.8
- o Boiler load factor of approximately 54% is assumed for boilers originally designed for oil and derated by 75%; i.e., load factor =

  Rated capacity x 0.9 x 0.8 x 0.75

- o The thermal efficiency of the existing Navy oil fired boilers retrofitted to cofiring (oil and RDF) process is 77%. For 100% oil fired, 80% efficiency was used.
- o As-fired #6 fuel oil cost is $0.91 per gallon. (9)
- o As-fired #2 distillate fuel cost is $1.21 per gallon. (9)
- o The number of boiler plant operations personnel required for the retrofitted plant will be same as for the 100% oil burning boiler plant.
- o Construction period for the RDF storage and retrieval facilities and boiler retrofit system is one year.
- o The design, engineering, installation, and operating expenses related to the handling, storage, and retrieval of the RDF at the boiler plant site will be borne by the Navy.
- o The total capital investment cost (the Navy obligations only) shall include the following:
    - Installed equipment
    - Support facilities (support structure, utilities hook-up etc.)
    - Contingency @ 10% of facilities estimate
    - Facility design engineering fee @ 8%
    - Start-up costs @ 5% of capital investment
- o The incremental cost (labor and material supplies) associated with the operation and maintenance of the RDF storage, handling and retrieval system shall be taken into consideration in conducting the cost and benefit analysis. The operation and maintenance cost (O&M) shall include the following:
    - Operating labor @ $10.26 per hour on the basis of 2080 hours per year (as applicable)

- Maintenance labor (boiler plant only) @ 2% of capital investment
- Plant supervision cost @ 15% of plant operating labor
- Administrative labor @ 20% of operating, maintenance and supervision labor costs
- Payroll burden @ 31% of all labor
- Water and sewer for RDF storage and handling facilities @ \$1.50/1,000 gallons
- Electricity for RDF storage and retrieval facility @ 5.5¢ per kwh
- Additional ash disposal @ \$11.50 per ton

B.2 CONCEPT OF OPERATIONS

The basic concept of operations provides for:

- o Retrofitting two boilers for a plant with three or four boilers.
- o Retrofitting three boilers for a plant having five or more boilers.

In a site specific analysis, the total plant production would have to be considered to be a product of firing both the retrofitted co-fired boilers and the stand-by fossil fuel-fired boilers. For the generic analyses, however, the total plant production will be assumed to be generated by the retrofitted boilers only.

B.3 PLANT OPERATIONS

The RDF consumption per day or per year can be stated in terms of:

$$W_R = \frac{Q_o \times t}{Be_2} \times \frac{1}{HHV_R \times 2000 \text{ lbs/ton}} \times CF \times P_R$$

where: W_R = Weight of RDF in Tons/year

Q_o = energy output of boiler in MBtu/hour

t = time period = 24 hours/day

Be_2 = boiler efficiency for 20% RDF/80% oil

= 77%

HHV_R = high heat value of RDF = 6,588 Btu/lb.

CF = load factor = 90% of capacity

P_R = percent RDF

For one 50 MBtu/hr. (output) boiler:

$$W_R = \frac{50 \times 10^6 \times 24}{0.77} \times \frac{1}{6,588 \times 2000} \times 0.9 \times 0.2$$

W_R = 21.29 tons/day

Annual RDF conumption for a 50 MBtu/hr. boiler, assuming an operation of 292 days per year:

W_R = 21.29 tons/day x 292 days/year

W_R = 6,216.68 tons/year

The daily oil consumption per boiler would be:

$$W_o = \frac{Q_o \times t}{Be_2} \times \frac{1}{HHV_o \times 2000 \text{ lbs/ton}} \times CF \times P_o$$

where: W_o = Weight of Oil

HHV_o = High heat valve of oil = 18,300 Btu/lb

P_o = percent oil

For one 50 MBtu/hr. (output) boiler:

$$W_o = \frac{50 \times 10^6 \times 24}{0.77} \times \frac{1}{18,300 \times 2000} \times 0.9 \times 0.8$$

= 30.66 tons/day

Annual oil consumption, assuming 292 days of operation per year:

W_o = 30.66 tons/day x 292 days/yr.

= 8,952.72 tons/year = 2,295,569 gals/yr.

Oil saved as a result of the co-firing of RDF and oil, versus oil alone, would equal:

$$W_o \text{ (saved)} = W_o \text{ (100\% oil-fired)} - W_o \text{ (20\% RDF/80\% oil-fired)}$$

where:

$$W_o \text{ (100\% oil-fired)} + \frac{Q_o \times t}{Be_1} \times \frac{1}{HHV_o \times 2000 \text{ lbs/ton}} \times CF$$

$$= \frac{50 \times 10^6 \times 24}{0.8} \times \frac{1}{18{,}300 \times 2000} \times 0.9$$

$$= 36.885 \text{ tons/day}$$

$$= 10{,}770.50 \text{ tons/year}$$

$$W_o \text{ (saved)} = 10{,}770.50 \text{ tons/year} - 8{,}952.72 \text{ tons/year}$$

$$W_o \text{ (saved)} = 1{,}817.78 \text{ tons/year (for one 50 MBtu/hr. boiler)}$$

$$= 462{,}007.5 \text{ gals/year}$$

The ash generated as a result of the co-fired RDF and oil operation with one 50 MBtu/hr. boiler, would equal:

$$W_A = W_R \times P_{AR} + W_o \times P_{Ao}$$

$$= 21.29(0.13) + 30.66(0.004)$$

$$= 2.89 \text{ tons/day} = 843.88 \text{ tons/yr.}$$

where: W_A = Weight of ash

P_{AR} = Ash content of RDF = 13% by weight

P_{Ao} = Ash content of oil = 0.4% by weight

Table B-1 provides a summary of gross production, fuel consumption, and fuel savings for boilers operating 24 hours per day, 292 days per year, 20% RDF and 80% oil, 77% boiler efficiency, at 90% of boiler capacity, and no derating.

Table B-1. Boiler Operations Summary.

Number of Boilers	Boiler Capacity (MBtu/hr)	Gross Production (MBtu/yr)	Fuel Consumption RDF (Tons/Yr)	Fuel Consumption Oil (Tons/Yr)	Oil Saved (Tons/Yr)	Oil Saved (Gals/Yr)
2	50	630,720	12,433	17,905	3,636	924,015
3	50	946,080	18,650	26,858	5,453	1,385,769
2	75	946,080	18,650	26,858	5,453	1,385,769
3	75	1,419,120	27,975	40,287	8,180	2,078,070
2	100	1,261,440	24,866	35,811	7,272	1,848,030
3	100	1,892,160	37,299	53,716	10,908	2,772,046
2	150	1,892,160	37,299	53,716	10,908	2,772,046
3	150	2,838,240	55,949	80,574	16,360	4,157,560

Table B-2 provides a summary of ash output for different boiler groups assuming 90% load factor, 20% RDF and 80% oil, 77% boiler efficiency, and ash content values for RDF and residual oil equal to 13% and 0.4%, respectively.

Table B-2. Ash Generation Summary.

Number of Boilers	Boiler Capacity (MBtu/hr)	RDF Tons/Day	Oil Tons/Day	Ash Generated Tons/Day	Ash Generated Tons/Year
2	50	42.54	61.32	5.78	1,687.76
3	50	63.82	91.98	8.67	2,531.95
2	75	63.82	91.98	8.67	2,531.95
3	75	95.81	137.97	13.01	3,797.92
2	100	85.10	122.64	11.56	3,375.94
3	100	127.69	183.96	17.34	5,063.90
2	150	127.69	183.96	17.34	5,063.90
3	150	191.59	275.94	26.01	7,595.85

B.4 ECONOMIC EVALUATION

B.4.1 Economic Model

The basic economic model can be stated in terms of:

$$COST_{DO} \times \frac{DF}{DF_N} \geq COST_{RDF} + \frac{NPV(I)}{DF_N} + \frac{NPV(I_R)}{DF_N} + \Delta OPS + \Delta MAINT$$
$$- \Delta SWR \pm \Delta OTHER$$

where:

$Cost_{DO}$	=	Total cost of displaced oil
DF_o	=	20 year discount factor for (Year 21 - year 1) oil @ +4% inflation = 11.367
DF_N	=	20 year normal discount factor (Year 21 - year 1) @ base inflation = 8.120
$Cost_{RDF}$	=	Total cost of RDF
NPV(I)	=	Net present value of Capital Investment
NPV(IR)	=	Net Present Value of Cost of Equipment Replacement
ΔOps	=	Change in operations costs as a result of co-firing boilers
ΔMaint	=	Change in maintenance costs
ΔSWR	=	Savings in solid waste removal
ΔOther	=	Other increases or decreases caused as a result of co-firing boilers

The costs of displaced oil is multiplied by DF_o/DF_N to account for oil inflating at a rate 4% faster than normal inflation. NPV(I) and $NPV(I_R)$ are divided by DF_N to reduce the total net present costs to annual capital cost recovery charges.

The cost of displaced oil ($Cost_{DO}$) x DF_o/DF_N - the cost of RDF ($Cost_{RDF}$) represents the Annual Fuel Cost Savings (AFCS).

The AFCS for a plant can also be stated as a direct function of fuel con-
›tion:

$$AFCS = \frac{Q_o}{Be_1}(T \times LF)\frac{(C_o\ DF_o)}{DF_N} - \frac{Q_o}{Be_2}(T \times LF)(P_o C_o \frac{DF_o}{DF_N}) - \frac{Q_o}{Be_2}(T \times LF)(P_R C_R)$$

where: Q_o = Capacity of boiler(s) in terms of Btu/hr.

Be_1 = Boiler efficiency, oil only

Be_2 = Boiler efficiency, co-fired

T = Hours per year = 8,760

LF = Load factor = percent use x operating level; i.e. 80% use @ 90% capacity = 0.72

P_R = Percent Btu input from RDF

C_R = Cost of RDF per 10^6 Btu input

P_o = Percent Btu input from oil

C_o = Cost of oil per 10^6 Btu input

DF_o = 20 yr. discount factor for oil @ + 4% inflation = 11.365

DF_N = 20 yr. normal discount factor @ Base Inflation Rate = 8.120

residual oil costing \$0.91 per gallon with a high heat value of 18,300 lb. and weighing 7.87 lbs. per gallon, the average fuel cost is \$6.318 per Btu input.

2 Economic Analysis Parameters

a. Constants. The following factors will be treated as constants in the ...ations:

HHV_{RDF} = 6,588 Btu/lb.

HHV_{oil} = 18,300 Btu/lb.

- LF = 0.72 for full firing boilers and 0.54 for derated boilers
- T = 8,760 hours/year
- C_o = $6.318
- DF_{oil} = 11.367
- DF_N = 8.120

b. Variables. The following factors will be varied to test the effect on the AFCS evaluations:

- Boiler efficiency - from 75% to 80%
- Boiler capacity - from full capacity (100%) to derated capacity (75%), to show the effect if derating is required
- RDF unit costs

B.4.3 Annual Fuel Cost Savings (AFCS)

Table B-3 shows the AFCS factors for different cost and operating conditions.

Table B-3. Annual Fuel Cost Savings.

RDF Price		ANNUAL FUEL COST SAVINGS					
		Boiler(s) Rated Output Capacity - 10^6 Btu/Hour					
		100	150	200	250	300	450
($/Ton)	($/MBtu)	($000)	($000)	($000)	($000)	($000)	($000)
80% Co-firing Boiler Efficiency - No Derating							
0	0	1,144	1,715	2,286	2,868	3,429	5,144
5	0.379	1,083	1,624	2,166	2,707	3,248	4,873
10	0.759	1,023	1,534	2,046	2,557	3,069	4,603
15	1.138	963	1,445	1,926	2,408	2,889	4,334
20	1.518	903	1,355	1,806	2,258	2,710	4,064
25	1.897	843	1,265	1,687	2,109	2,530	3,795
30	2.277	784	1,175	1,567	1,959	2,351	3,526

Table B-3. Annual Fuel Cost Savings (Continued).

RDF Price		ANNUAL FUEL COST SAVINGS					
		Boiler(s) Rated Output Capacity - 10^6 Btu/Hour					
		100	150	200	250	300	450
($/Ton)	($/MBtu)	($000)	($000)	($000)	($000)	($000)	($000)
77% Co-firing Boiler Efficiency - No Derating							
0	0	1,177	1,766	2,354	2,943	3,531	5,297
5	0.379	1,115	1,673	2,230	2,788	3,345	5,018
10	0.759	1,053	1,579	2,106	2,632	3,159	4,738
15	1.138	991	1,486	1,982	2,477	2,972	4,459
20	1.518	929	1,393	1,857	2,321	2,786	4,179
25	1.897	866	1,299	1,733	2,166	2,599	3,899
30	2.277	804	1,206	1,608	2,011	2,413	3,619
75% Co-firing Boiler Efficiency - No Derating							
0	0	1,202	1,803	2,404	3,005	3,606	5,409
5	0.379	1,138	1,707	2,275	2,844	3,413	5,120
10	0.759	1,074	1,611	2,148	2,685	3,221	4,832
15	1.138	1,010	1,515	2,020	2,525	3,030	4,545
20	1.518	946	1,419	1,892	2,365	2,839	4,258
25	1.897	882	1,324	1,765	2,206	2,647	3,971
30	2.277	819	1,228	1,637	2,046	2,456	3,683
80% Co-firing boiler Efficiency - Boilers Derated by 75%							
0	0	857	1,286	1,715	2,144	2,572	3,858
5	0.379	812	1,218	1,624	2,030	2,437	3,654
10	0.759	767	1,151	1,534	1,918	2,301	3,452
15	1.138	722	1,084	1,445	1,805	2,167	3,251
20	1.518	677	1,016	1,355	1,693	2,032	3,048
25	1.897	632	949	1,265	1,581	1,898	2,847
30	2.277	588	881	1,175	1,469	1,763	2,644
77% Co-firing Boiler Efficiency - Boilers Derated by 75%							
0	0	883	1,325	1,766	2,207	2,648	3,973
5	0.379	836	1,255	1,673	2,091	2,509	3,764
10	0.759	790	1,185	1,579	1,974	2,369	3,554
15	1.138	743	1,115	1,486	1,858	2,229	3,344
20	1.518	696	1,045	1,393	1,741	2,089	3,134
25	1.897	650	975	1,299	1,625	1,950	2,924
30	2.277	603	905	1,206	1,508	1,809	2,714

Table B-3. Annual Fuel Cost Savings (Continued).

RDF Price		ANNUAL FUEL COST SAVINGS					
		Boiler(s) Rated Output Capacity - 10^6 Btu/Hour					
		100	150	200	250	300	450
($/Ton)	($/MBtu)	($000)	($000)	($000)	($000)	($000)	($000)
75% Co-firing Boiler Efficiency - Boilers Derated by 75%							
0	0	902	1,352	1,803	2,254	2,705	4,057
5	0.379	853	1,280	1,706	2,133	2,560	3,840
10	0.759	805	1,208	1,611	2,013	2,416	3,624
15	1.138	758	1,136	1,515	1,894	2,273	3,409
20	1.518	710	1,064	1,419	1,774	2,129	3,193
25	1.897	662	993	1,324	1,655	1,985	2,978
30	2.277	614	921	1,228	1,534	1,842	2,763

B.4.4 Capital Investment Costs

B.4.4.1 Design Factors

a. General

The primary storage facilities shall be designed on the basis of table B-1 daily consumption data accelerated by 80% to cover irregularities in delivery, load demand, plant operations, etc. RDF is assumed to be delivered on the average 7 days per week 52 weeks per year.

All other RDF systems including the conveyor systems, intermediate storage bins, pre-feed mills, pneumatic delivery systems, boiler modifications and ash collection systems shall be based on operations at 100% of boiler capacity vice the 90% load factor used in developing table B-1.

b. RDF Storage System Design

The RDF storage system will consist of two Atlas bins, allowing one to be filled while one is being drawn-down. The total storage requirements for one 50 MBtu/hr. boiler would equal:

$$S_R = W_R \times F_S = 21.29 \text{ tons/day} \times 1.8$$

$$= 38.32 \text{ tons/day}$$

where: S_R = RDF storage

F_S = storage factor = Unity + 80% for delivery and production variances

Two 20-ton storage bins would be used for a single boiler operation, two 40-ton bins for a double boiler operation, and two 60-ton bins for a three boiler operation.

Table B-4 provides a size and cost comparison for various storage units for different boiler plant operations, based on using a double bin operation. Usage of a single bin in lieu of twin or double bins would reduce costs by 30 to 35% but would remove the redundancy capability.

Table B-4. Capital Costs Summary (Atlas Storage Bins).

Number of Boilers	Boiler Output (MBtu/hr.)	Storage Requirements (Tons)	Storage Design (No. - Bin Size)	Cost of[1] Installation ($000)
1	50	40	2-20	672
2	50	80	2-40	882
3	50	120	2-60	1,036
1	75	60	2-30	787
2	75	120	2-60	1,036
3	75	180	2-90	1,217
1	100	80	2-40	882
2	100	160	2-80	1,159
3	100	240	2-125	1,386
1	150	120	2-60	1,036
2	150	240	2-125	1,386
3	150	360	2-180	1,602

Note: [1] Installation costs include concrete slab and foundation, and electrical/mechanical.

c. <u>Conveyor System</u>

The conveyor system shall include:

- o RDF receiving conveyor - 48 in. by 100 ft. long
- o Hopper bottom and lift - 48 in. x 150 ft. long
- o Storage bin top - 48 in. x 50 ft. long
- o Bin discharge conveyor - 36 in. x 50 ft. long
- o Mill feed - 36 in. x 120 ft. long
- o Excavation and support system
- o Sheet metal skirts along belt bath

All conveyor drives will have variable speed motors.

d. <u>Intermediate Storage Bin</u>

The intermediate storage bin will be a "live-bottom" surge bin.

e. <u>Prefeed Mill</u>

The prefeed mill will be the Doffin-Roll-bin type.

f. <u>Pneumatic Delivery System</u>

The pneumatic delivery system shall include blower, valves, distribution system, 8-inch diameter pipe, structural support and foundation. The pneumatic system piping will be provided with renewable/replaceable wear plates at critical locations in the transport line.

g. <u>Boiler Modifications</u>

The boiler modifications shall include:

- o Dump grate (3 sections)
- o RDF feed pipe
- o Air swept jets
- o Grate underfire air distribution
- o Grate overfire air distribution

The boiler modifications shall provide for the RDF feedrate (by weight) to be kept constant and the boiler swing load demand to be carried by modulating the oil input rates.

Any decision to install dump grates should be coordinated with the boiler manufacturer.

In some installations relocation of the gas recirculation system will be required for NO_x control. In such relocation the flue gas duct would have to be relocated. No costs were included for this type work.

h. Dust Collection System

The dust collection system shall be a Pulse-Jet design using filter bags. It is assumed that no dust collection (or air pollution control) system exists.

i. Ash Handling System

The design will be based on an ash collection system or hopper existing, but no ash handling or removal system available.

B.4.4.2 Capital Investment Cost Estimates

Table B-5 shows the different capital investment costs estimated for each boiler system planned for retrofit, based on vendors quotes obtained via a telephone survey. The vendors quotes also contain the current 1983 costs to install the systems including structural modifications and foundation supports.

B.4.5 O&MN Costs

Table B-6 reflects the increased or supplemental costs that may be experienced annually in the operation of the Navy boilers and RDF storage and delivery systems. The individual factors are based on the following:

- Electricity:

  Rated HP x 0.746 KW/HP x 24 hrs./day x 292 days x 5.5¢ per KwH

  For 100 MBtu/Hr. boiler capacity, require 50 HP cap.

TABLE B-5

CAPITAL INVESTMENT COST SUMMARY

NAVY BOILER PLANT MODIFICATIONS

CAPITAL INVESTMENT COST CATEGORY	50 MBtu/hr Boilers		75 MBtu/hr Boilers		100 MBtu/hr Boilers		150 MBtu/hr Boilers	
	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers
	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)
1. Primary Storage Atlas Bins	$882	$1,036	$1,036	$1,217	$1,159	$1,386	$1,386	$1,602
2. Conveyor System Sub-Systems	60	90	75	105	85	120	105	138
3. Intermediate Storage Bin	75	90	85	110	92	130	115	153
4. Prefeed Mill Doffing Roll Pin	95	125	110	145	123	158	142	178
5. Pneumatic Delivery System	240	300	290	360	328	418	360	433
6. Boiler Mods & Equipment	300	390	345	470	386	550	401	598
7. Dust Collection System	220	280	240	320	252	353	317	380
8. Ash Handling System	30	39	35	47	39	55	40	60
9. General Mechanical	95	110	100	125	105	128	135	175
10. General Electrical	75	90	85	100	89	102	117	135
11. Sub Total	2,072	2,550	2,401	2,999	2,658	3,400	3,118	3,852
12. 10% Contingency	207	255	240	300	266	340	312	385
13. 5% Start-Up Cost	104	128	120	150	133	170	156	198
14. Sub-Total	2,383	2,933	2,761	3,449	3,057	3,910	3,586	4,435
15. Design (8%)	191	235	221	276	245	313	287	355
16. Total Costs	$2,574	$3,168	$2,982	$3,725	$3,302	$4,223	$3,873	$4,790

TABLE B-6

O & M SUPPLEMENTAL COSTS

O & M COST CATEGORY	50 MBtu/hr Boilers		75 MBtu/hr Boilers		100 MBtu/hr Boilers		150 MBtu/hr Boilers	
	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers	2 Boilers	3 Boilers
	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)
OPERATIONS								
UTILITY TRANSFER								
Electrical	15	17	17	21	21	25	25	30
Water & Sewage	13	14	14	15	15	16	16	18
WASTE REMOVAL								
Land Fill Costs	36	53	53	80	72	106	106	159
MAINTENANCE								
Labor	52	63	60	75	66	84	77	96
Materials	42	50	48	60	53	67	62	77
Sub Total	158	197	194	251	227	298	286	380
Administrative	29	37	34	43	38	48	44	55
Sub Total	187	234	228	294	265	346	330	435
Contingency (10%)	19	23	23	29	27	35	33	44
TOTAL O & M	$206	$257	$251	$323	$292	$381	$363	$479

For 150 MBtu/Hr. boiler capacity, require 60 HP cap.

For 200 MBtu/Hr. boiler capacity, require 75 HP cap.

For 300 MBtu/Hr. boiler capacity, require 85 HP cap.

For 450 MBtu/Hr. boiler capacity, require 100 HP cap.

- Water:

  Water requirements (1000 gals.) per year x $1.50/1000 gal.

- Landfill costs:

  Ash disposal in landfill @ $21.30 per ton including transport.

- Maintenance labor cost:

  Estimated labor = 2% of capital investment costs.

- Maintenance material cost:

  Estimated materials = 80% of maintenance labor.

- Adminstration:

  Includes 20% of maintenance labor for administrative labor and 31% payroll burden rate for both maintenance and administrative labor increases.

B.4.6 Annual O&M and Capital Investment Cost Factors

The basic economic model has already been outlined in section B.4.1; i.e.:

$$AFCS \geq \frac{NPV(I)}{DF_N} + \frac{NPV(I_R)}{DF_N} + \Delta Ops + \Delta Maint - \Delta Solid\ Waste\ Removal \pm \Delta Other$$

The annual fuel cost savings (AFCS) are summarized for each boiler group in section B.4.3.

The capital investment costs and O&M costs summarized in tables B-5 and B-6 can be redefined in terms of an annual cost factor to be plotted against the annual fuel cost savings (AFCS) factors to determine the breakeven point or net profit for each group of boilers.

The capital investment and O&M cost factors can be stated as follows:

- o The annual charge to recover the original capital investment ($NPV(I)/DF_N$) is equal to the Net Present Value of the capital investment, using 0.954 as the discount factor for the year during which construction is occurring, divided by the 20-year cumulative discount factor, 9.074 (year 21) - 0.954 (year 1) = 8.120.
- o The annual charge to recover the capital investment to replace equipment ($NPV(I_R)/DF_N$) is equal to zero in this analysis. An accelerated maintenance and repair program is used in lieu of equipment replacement.
- o The change in operating cost (ΔOps) is equal to increase in the electricity, water and ash disposal.
- o The change in maintenance (ΔMaint) is equal to the increase in maintenance labor and materials to maintain the RDF system and boiler.
- o The solid waste consumed in producing RDF will predominately come from municipal waste due to the small volume generated by the Navy. It is assumed that the tipping fee costs will be equal to the rate for the alternative for disposal of municipal waste which will be equal to or greater than the cost of the Navy disposal method.

Therefore, the savings in Navy solid waste removal (ΔSWR) is treated as zero in this analysis assuming that the cost to dispose of solid waste is the same whether the Navy uses landfill disposal or pays a solid waste processing plant to take the refuse.

- Administrative costs (ΔOther) include labor and payroll benefits required to support the increased maintenance requirement.

Maintenance variances of (+80%) and (-20%) covering labor and materials, are used to provide a sensitivity test of operations to determine the impact of major repair or overhaul variances being experienced above or below the plan. No equipment replacement is planned.

A sample calculation to develop the annual applied cost factor is provided as follows:

<u>100 MBtu/hr. boiler plant (two 50 MBtu/hr. boilers)</u>

$$NPV(I) = \$2574{,}000 \times 0.954 = \$2{,}455{,}596$$

$\frac{NPV(I)}{DF_N} = \frac{\$2{,}455{,}596}{8.120}$	\$ 302,413
$\frac{NPV(I_R)}{DF_N}$	0
ΔOps + ΔMaint + ΔOther (from table B-6)	206,000
ΔSWR	0
Estimated Annual Applied Cost	\$ 508,413

Applying the maintenance variances:

High Cost Estimate	\$ 583,613
(\$508,413 + 0.8 x \$94,000)	
Probable Cost Estimate	508,413
Low Cost Estimate	489,613
(\$508,413 - 0.2 x \$94,000)	

From the other boiler groups:

- o <u>150 MBtu/hr. boiler plant (three 50 MBtu/hr. boilers)</u>

High Cost Estimate	$ 719,601
Probable Cost Estimate	629,201
Low Cost Estimate	606,601

- o <u>150 MBtu/hr. boiler plant (two 75 MBtu/hr. boilers)</u>

High Cost Estimate	$ 687,748
Probable Cost Estimate	601,348
Low Cost Estimate	579,748

- o <u>200 MBtu/hr. boiler plant (two 100 MBtu/hr. boilers)</u>

High Cost Estimate	$ 775,144
Probable Cost Estimate	679,944
Low Cost Estimate	656,144

- o <u>225 MBtu/hr. boiler plant (three 75 MBtu/hr. boilers)</u>

High Cost Estimate	$ 868,642
Probable Cost Estimate	760,642
Low Cost Estimate	733,643

- o <u>300 MBtu/hr. boiler plant (three 100 MBtu/hr. boilers)</u>

High Cost Estimate	$ 997,950
Probable Cost Estimate	877,150
Low Cost Estimate	846,950

- o <u>300 MBtu/hr. boiler plant (two 150 MBtu/hr. boilers)</u>

High Cost Estimate	$ 929,230
Probable Cost Estimate	818,030
Low Cost Estimate	790,230

- 450 MBtu/hr. boiler plant (three 150 MBtu/hr. boilers)

High Cost Estimate	\$1,180,166
Probable Cost Estimate	1,041,766
Low Cost Estimate	1,007,166

B.4.7 Breakeven Point Analysis

Figures B-1 through B-6 provide cost curves for each boiler group comparing annual fuel cost savings for different boiler ratings and efficiencies, with RDF unit prices and O&M costs. The annual fuel cost savings (AFCS) are extracted from table B-3. The capital recovery costs and O&M costs are derived in section B.4.6. The most probable values of the capital recovery and O&M costs were used to plot against the AFCS values.

In 5 of the 6 generic cases, the breakeven point was well off the graph indicating a substantial savings for the larger boiler groups with RDF costs at maximum value. In the 1 case where breakeven points could be observed, the boilers were required to be derated and the allowable price of RDF ranged between \$35 and \$40 per ton. In comparison, the overall evaluations could better be stated in terms of savings-to-investment ratios (SIRs) and discounted payback periods.

B.4.8 Savings-to-Investment Ratios and Payback Periods

Assuming a normalized set of conditions; i.e. each boiler is at full rating and is operating in a co-fired mode at 77% efficiency, 90% of capacity continuously 24 hours per day, 292 days per year; and RDF is purchased at \$30 per ton; then a savings-to-investment ratio and discounted payback period could be developed for each group of boilers as follows:

$$\text{S.I.R.} = \frac{\text{O\&M Savings per Year}}{\text{Capital Recovery Cost per Year}}$$

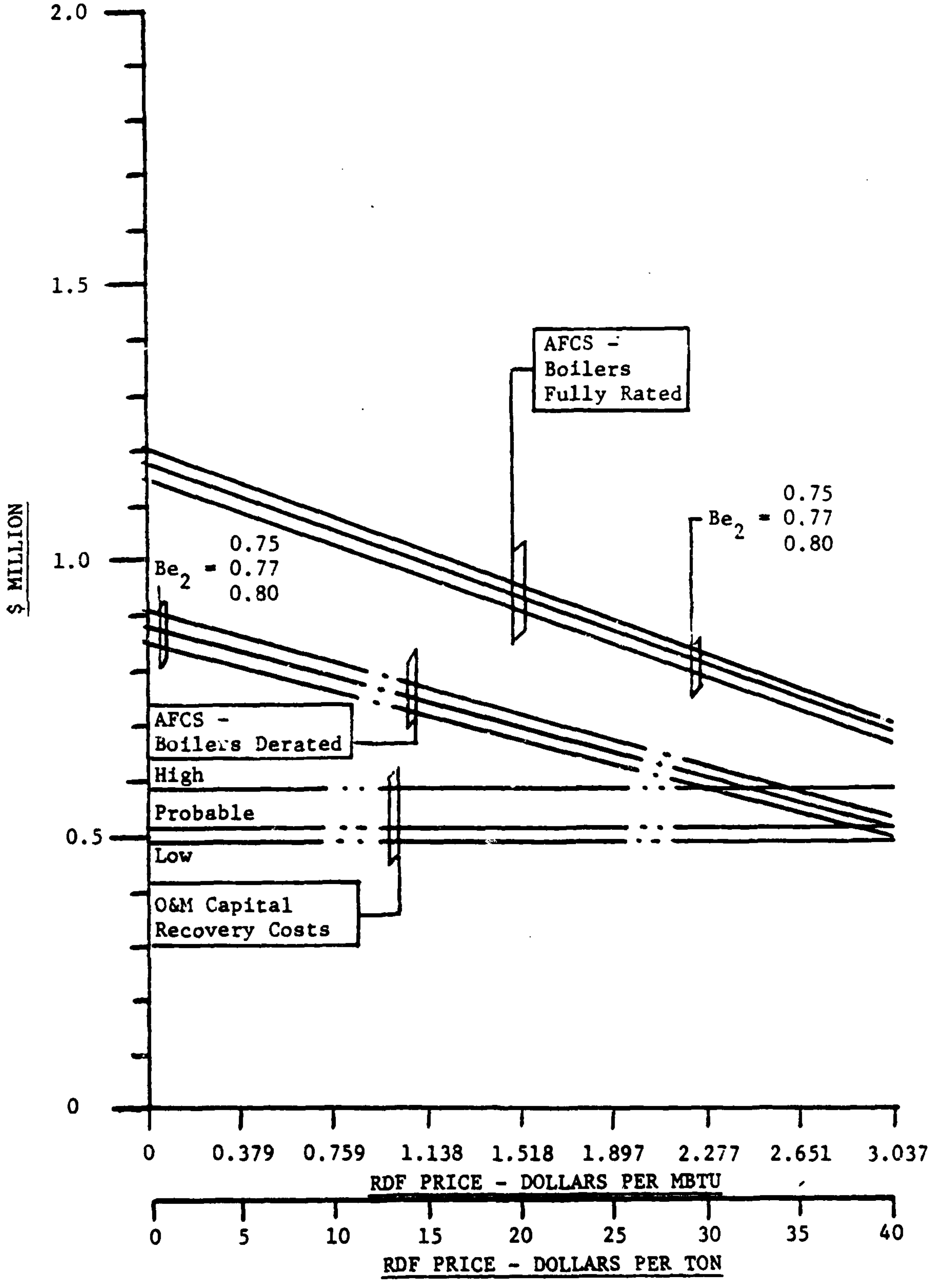
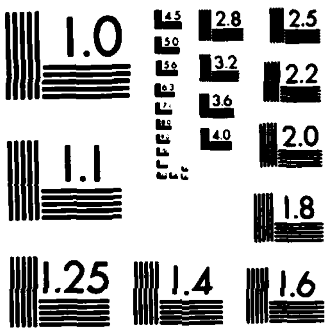


Figure B-1. Comparison of Annual Fuel Cost Savings to O&M, RDF, and Capital Recovery Costs for a Boiler Capacity of 100 MBtu/hr (2-50 MBtu/hr Boilers).

AD-A130 444 RDF (REFUSE DERIVED FUEL) UTILIZATION IN A NAVY 2/2
OIL-FIRED BOILER(U) VSE CORP OXNARD CA
G H GARDINER ET AL. JUN 83 NCEL-CR-83.033
UNCLASSIFIED N00123-82-C-0149 F/G 13/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

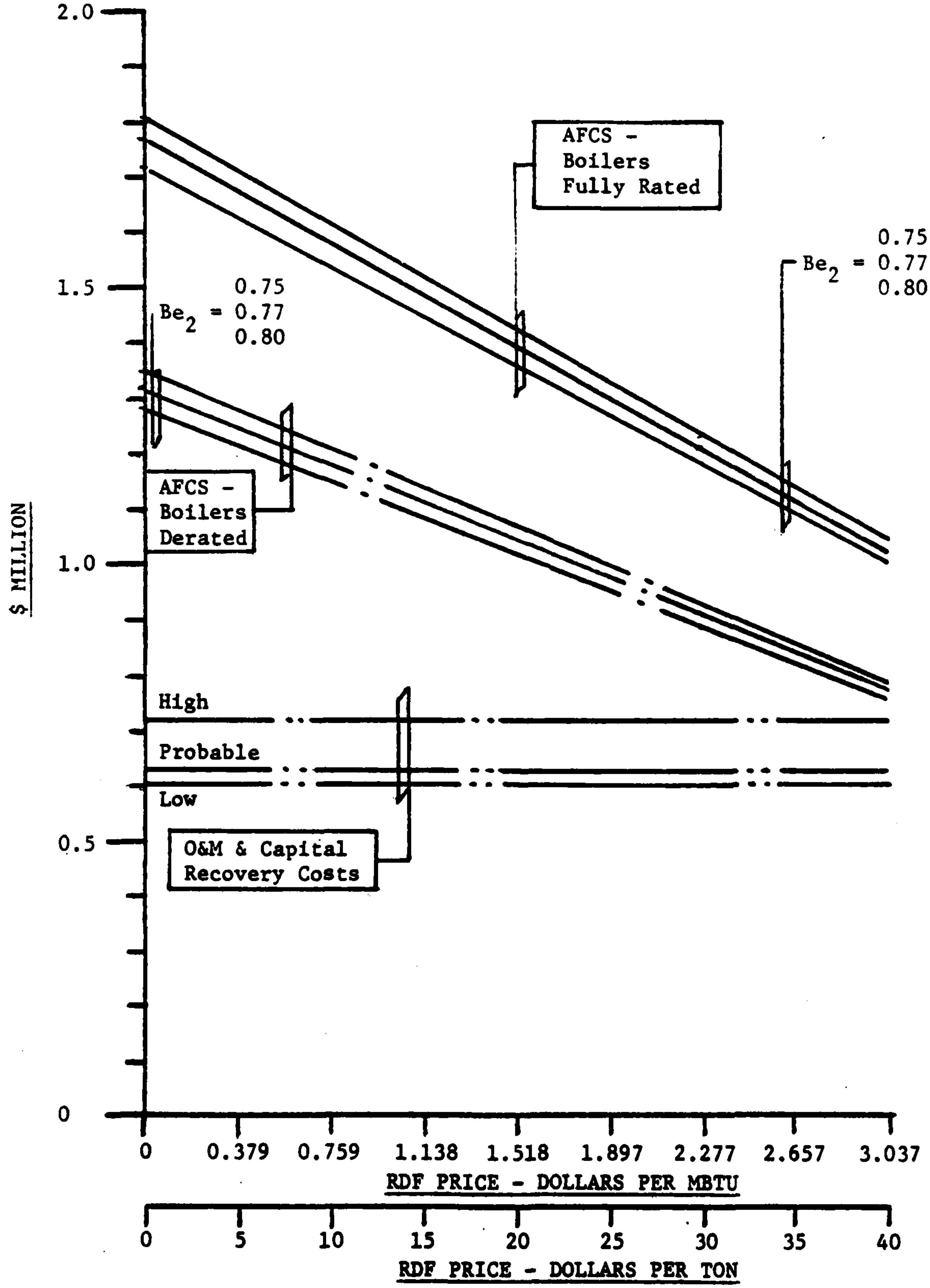


Figure B-2. Comparison of Annual Fuel Cost Savings to O&M, RDF, and Capital Recovery Costs for a Boiler Capacity of 150 MBtu/hr (3-50 MBtu/hr Boilers).

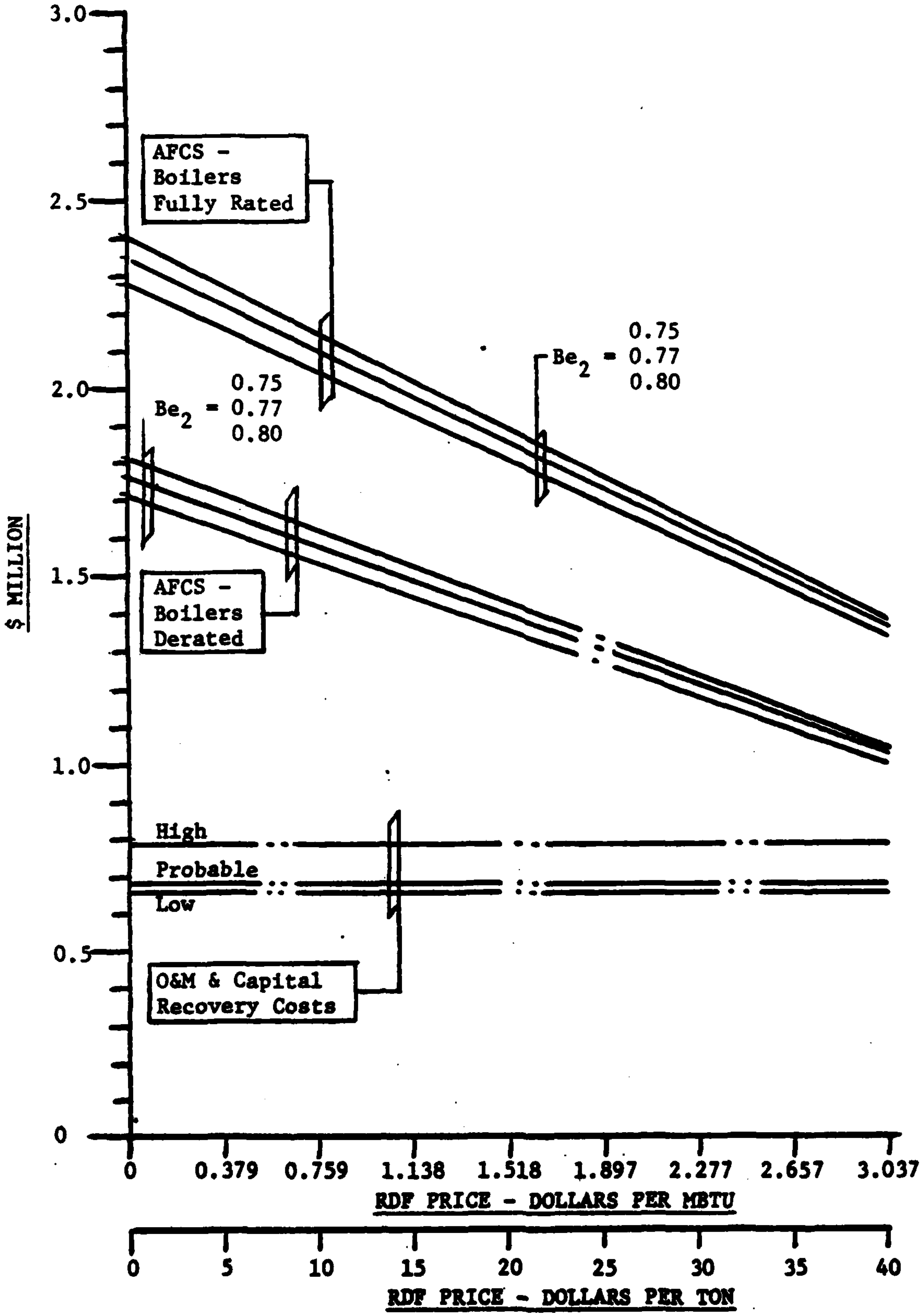


Figure B-3. Comparison of Annual Fuel Cost Savings to O&M, RDF and Capital Recovery Costs for a Boiler Capacity of MBtu/hr (2-100 MBtu/hr Boilers).

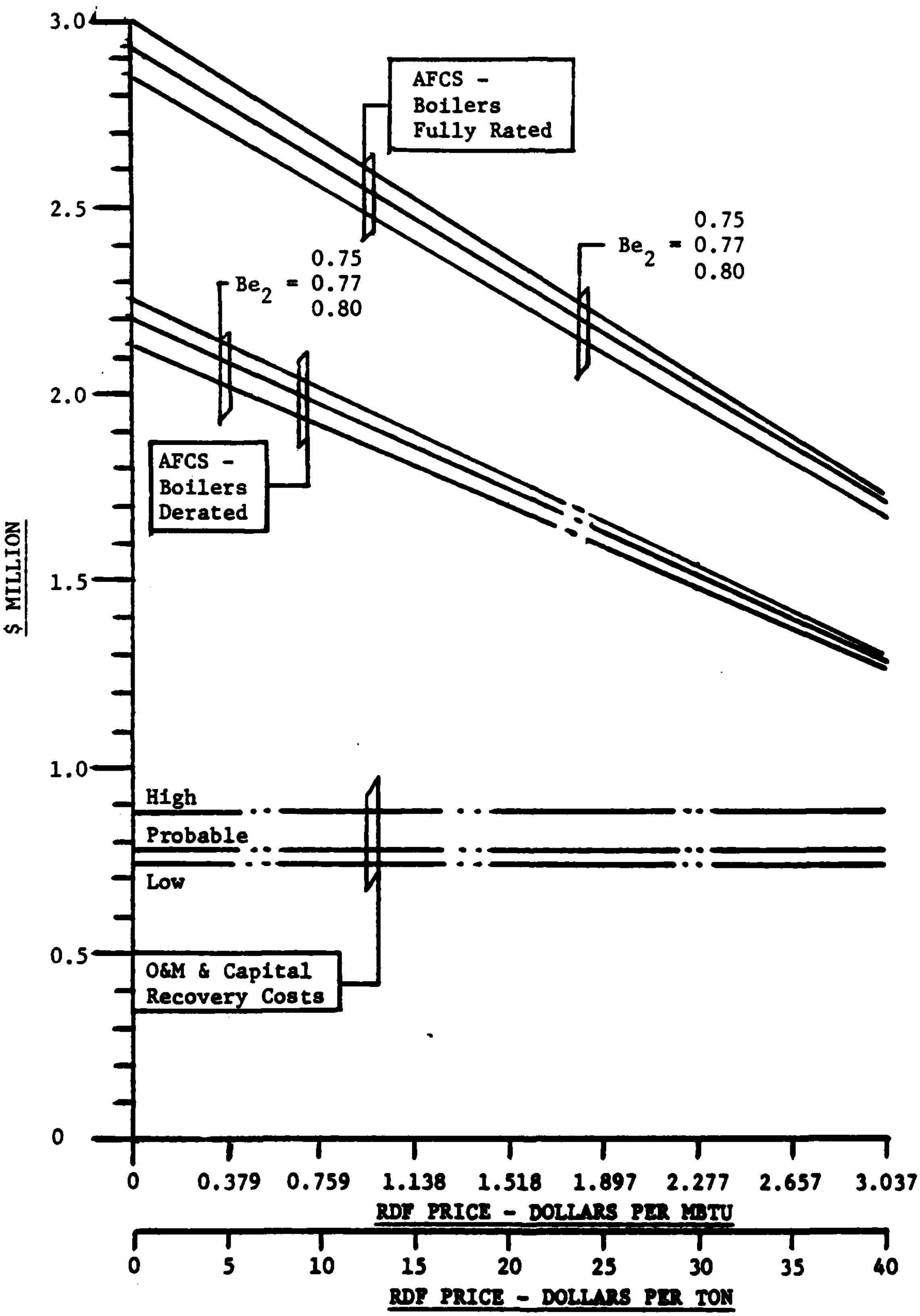


Figure B-4. Comparison of Annual Fuel Cost Savings to RDF, O&M, and Capital Recovery Costs for Boiler Capacity of 250 MBtu/hr (2-125 MBtu/hr Boilers).

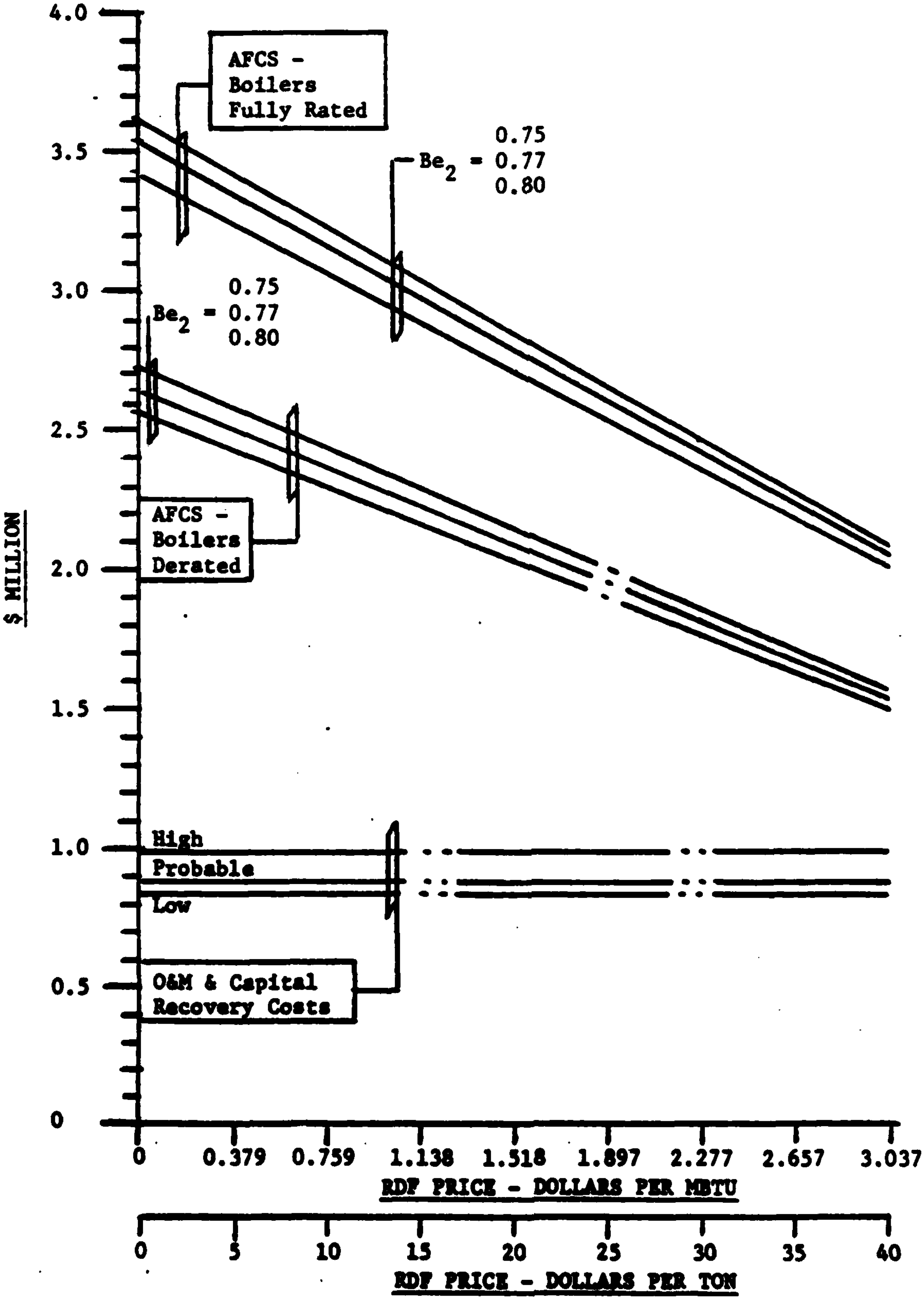


Figure B-5. Comparison of Annual Fuel Cost Savings to O&M, RDF, and Capital Recovery Costs for a Boiler Capacity of 300 MBtu/hr (3-100 MBtu/hr Boilers).

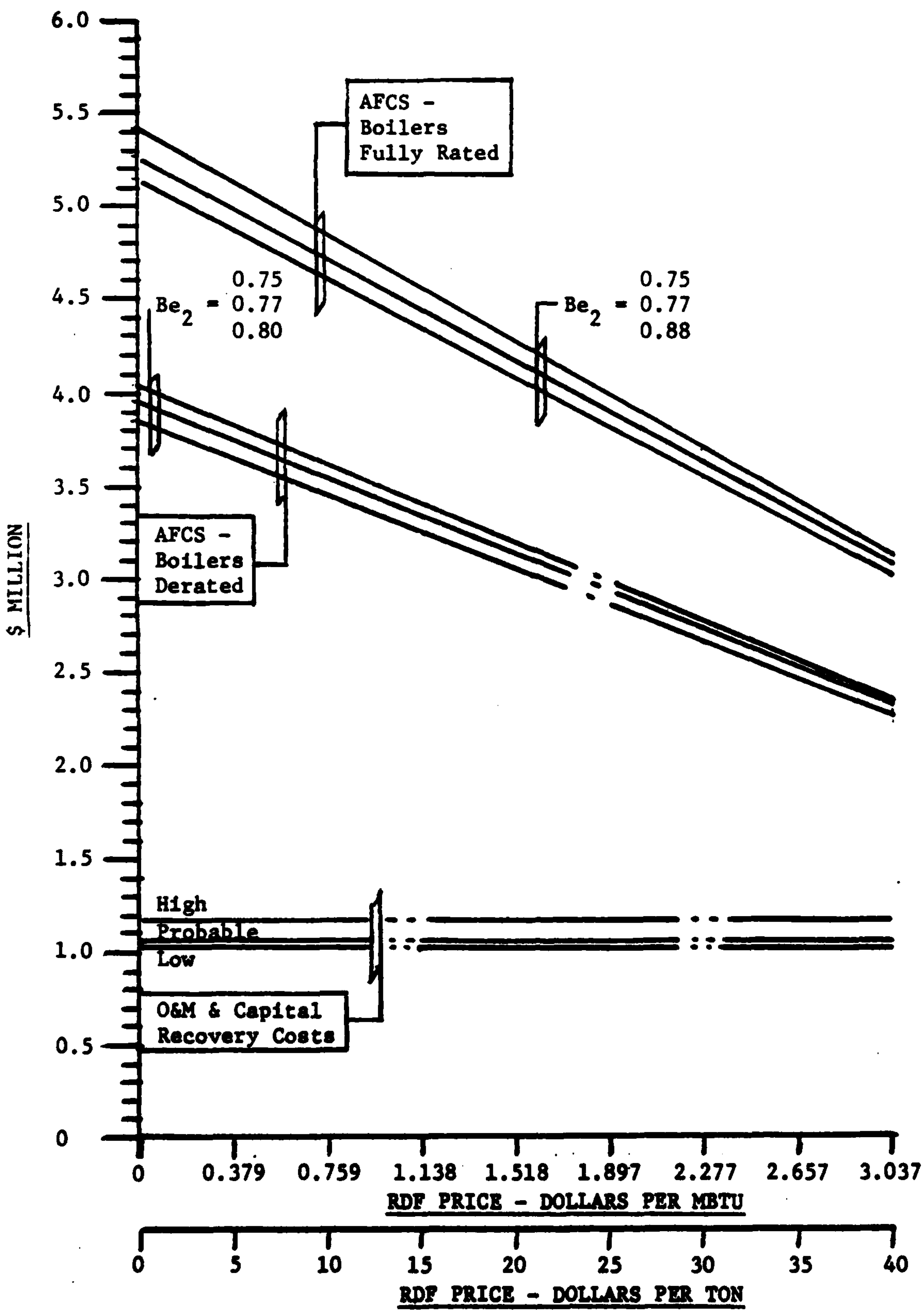


Figure B-6. Comparison of Annual Fuel Cost Savings to O&M, RDF, and Capital Recovery Costs for a Boiler Capacity of 450 MBtu/hr (3-150 MBtu/hr Boilers).

For two 50 MBtu/hr. boilers or 100 MBtu/hr. capacity:

O&M Savings per Year = AFCS - $\triangle$O&M

= \$804,000 - \$206,000

= \$598,000

Capital Recovery Costs per Year = \$302,413

Therefore:

$$S.I.R. = \frac{\$598,000}{\$302,413} = 1.98$$

For an S.I.R. of 1.98 and an economic life of 20 years, referring to the conversion table in the Economic Analysis Handbook, the discounted payback period would equal 5.90 years.[10]

For each of the 6 generic classes of boiler facilities:

Total Boiler Group Capacity (MBtu/hr.)	S.I.R.	Discounted Payback Period
100	1.98	5.90 years
150	2.73	3.92 years
200	3.39	3.03 years
250	4.01	2.50 years
300	4.51	2.20 years
450	5.58	1.73 years

B.5 SITE SPECIFIC REVIEWS

Six naval installations currently fire residual oil, distillate fuel or natural gas and are considered to be technically suitable to co-fire RDF and residual oil.

B.5.1 Naval Education and Training Center, Newport, RI

The avilable assets to be considered for conversion include two Riley Stoker, 75 MBtu/hr. boilers located in Bldg. 7. Both boilers were originally designed for coal and would not require derating. The total plant consists of 3 boilers having a gross capacity of 230 MBtu/hr. The third boiler in this

plant is inoperative. Without the third boiler, the plant cannot handle the station load during the cold season (5 months). Currently the plant is secured and another plant is placed in operations during the winter months.

The normal station annual operations are profiled as follows:

Gross production:	1,110,000 MBtu/yr.
High average (5 months):	140,000 MBtu/mo.
Mid average (3 months):	70,000 MBtu/mo.
Low average (4 months):	50,000 MBtu/mo.

The two boilers being considered cannot provide the entire load demand. With one boiler down through 5 months during the summer season, another boiler would be required to be placed on the line to provide approximately 10,000 MBtu/mo. for 5 months. During the winter months an additional boiler would have to be placed on line to provide 40,000 MBtu/mo. for 5 months. The net would be to reduce the gross production of the two Riley Stoker boilers to 860,000 MBtu/yr. maximum. If the third boiler in the plant was replaced, the annual O&M cost savings to be realized by co-firing RDF and oil in the two Reily boilers, assuming a mix efficiency of 77% and no derating, could possibly reach an O&M savings of $0.85 million per year with an RDF price of $30 per ton. With a capital investment equal to approximately $3.0 million:

- The savings-to-investment ratio would equal 2.41.
- The discount payback period would equal 4.58 years.

B.5.2 New London Subbase, CT

The available assets to be considered for conversion include:

- One Keeler, 96 MBtu/hr. boiler
- One Babcock-Wilcox, 106 MBtu/hr. boiler
- One Babcock-Wilcox, 99 MBtu/hr. boiler
- One Babcock-Wilcox, 92 MBtu/hr. boiler

All four boilers were originally designed for coal. Two Babcock-Wilcox boilers (106 MBTU/hr. and 99 MBtu/hr.) would require derating to burn RDF due to small furnace volume. Due to the fact that the four boilers represent the entire plant assets, only two (the 96 MBtu/hr. Keeler and 92 MBtu/hr. Babcock-Wilcox) boilers would be considered for conversion.

The normal station annual operations are profiled as follows:

Gross production:	1,110,000 MBtu/yr.
High average (5 months):	120,000 MBtu/mo.
Mid average (3 months):	90,000 MBtu/mo.
Low average (4 months):	60,000 MBtu/mo.

The 96 MBtu/hr. Keeler boiler and the 92 MBtu/hr. Babcock-Wilcox boiler could theroretically provide approximately 1,000,000 MBtu of the total steam production with an alternate boiler providing part of the production during the spring and/or fall.

The annual O&M cost savings to be realized by co-firng RDF and oil could possibly reach $0.95 million per year with an RDF price of $30 per ton. With a capital investment equal to approximately $3.3 million:

- o The savings-to-investment ratio would equal 2.46.
- o The discounted payback period would equal 4.48 years.

B.5.3 Naval Air Station, Alameda, CA

Three Keeler, 50 MBtu/hr. boilers are located within Bldg. 584, of which two could be candidates for conversion to co-fired RDF and distillate and waste oil, or residual oil, but were originally designed for coal.

Because the boiler plant is providing only a portion of the station demand, it is assumed that the two retrofitted boilers could be operated at optimum load to provide 630,720 MBtu/yr.

For the analysis, it is assumed that 920,000 gals of distillate fuel will be saved.

The annual O&M cost savings to be realized by co-firing RDF and oil could possibly reach $0.8 million per year with an RDF price of $30 per ton. With a capital investment equal to approximately $2.6 million:

- o The savings-to-investment ratio would equal 2.63.
- o The discounted payback period would equal 4.10 years.

B.5.4 Navy Public Works Center, Great Lakes, IL

The Great Lakes boiler plant currently has six boilers capable of generating 786 MBtu/hr. of steam. Four of the boilers are overaged but are capable of generating steam using natural gas. One 273 MBtu/hr. boiler is a package boiler. The remaining 273 MBtu/hr. boiler was originally designed for coal and is a potential condidate for conversion to co-fired RDF and residual oil.

The one boiler is capable of producing 1,703,000 MBtu of steam per year. However, Great Lakes currently uses natural gas to produce steam at a 1983 cost of $4.40 per MBtu (input); therefore, converting to 20% RDF plus 80% Residual Oil ($6.318 per MBtu) will produce a net loss of over $2 million . Therefore economically the Great Lakes boiler would not appear to be a suitable candidate.

B.5.5 Navy Public Works Center, Pensacola, FL

The Pensacola plant currently has three boilers capable of geneating 470 MBtu/hr. of steam. One boiler is a package boiler and can be used as the back-up boiler. The two Babcock-Wilcox, 125 MBtu/hr. boilers were originally designed for coal and are potential candidiates for conversion without derating.

The normal station annual operations are profiled as follows:

Gross production:	1,927,000 MBtu/yr.
High average (3 months):	200,000 MBtu/mo.

Mid average (7 months):	155,000 MBtu/mo.
Low average (2 months):	121,000 MBtu/mo.

The two Babcock-Wilcox boilers could theoretically provide 1,590,000 MBtu/yr. of the total steam production.

Pensacola currently fires its boilers with natural gas at a cost of $4.50 per MBtu (input). Replacing natural gas with RDF and residual oil ($6.318 per MBtu) will result in a net loss in excess of $2 million annually.

B.5.6 Mare Island Naval Shipyard, Vallejo, CA

Mare Island currently has three boilers capable of generating 480 MBtu/hr. of steam. One boiler is a package boiler and can be used for backup. The two Keeler 165 MBTU/hr. boilers were originally designed for coal and are potential candidates without derating.

The normal stations annual operations are profiled as follows:

Gross production:	750,000 MBtu/yr.
High average (3 months):	106,000 MBtu/mo.
Mid average (3 months):	80,000 MBtu/mo.
Low average (6 months):	32,000 MBtu/mo.

The two Keeler boilers could theoretically provide the entire steam load.

Mare Island curently fires its boilers on natural gas at a cost of $5.90 per MBtu (input). Replacing the natural gas with RDF and residual oil ($6.318 per MBtu) would not appear to be an economical alternative. The RDF would have to be obtained at a cost of $8.33 per ton and no funds would be available to payback the capital investment and O&M costs.

ANNEX C

EVALUATION OF NAVY BOILERS

C.1 INVENTORY

The Navy currently has 149 active boilers with a rated capacity of 50 MBtu/hr. or greater, categorized by primary fuel as follows:

Residual oil-fired .... 74 boilers

Distillate fuel-fired .... 10 boilers

Natural gas-fired .... 36 boilers

Residual oil (converted to coal) .... 19 boilers

Coal-fired .... 8 boilers

RDF-fired .... 2 boilers

C.1.1 <u>Residual Oil as a Primary Fuel</u>.

The Navy currently has seventeen installations using residual oil as a primary fuel. These activities include:

- <u>Portsmouth Naval Shipyard, N.H.</u>

  One Babcock-Wilcox, 185 MBTu/hr. boiler
  Three Edgemoor Iron Works, 150 MBtu/hr. boilers
  One Union Iron Works, 64 MBtu/hr. boiler

- <u>Naval Education and Training Center, Newport, R.I.</u>

  One Keeler, 110 MBtu/hr. boiler
  One Babcock-Wilcox, 50 MBtu/hr. boiler
  Two Riley Stoker, 80 MBtu/hr boilers
  One Babcock-Wilcox, 60 MBtu/hr. boiler
  Two Riley Stoker, 75 MBtu/hr. boilers

- <u>Naval Air Station, Brunswick, Me.</u>

  Four Babcock-Wilcox, 64-69 MBtu/hr. boilers

- <u>Naval Air Engineering Center, Lakehurst, N.J.</u>

  One Keeler, 55 MBtu/hr. boiler

Marine Corps Air Station, Cherry Point, N.C.

One Edgemoor Iron Works, 40 MBtu/hr. boiler
Two Wickes, 63 MBtu/hr. boilers

Marine Corps Base, Camp LeJuene, N.C.

One Trane, 100 MBtu/hr. boiler
Three Trane, 53 MBtu/hr. boilers
Two Combustion Engineering, 52 MBtu/hr. boilers

Marine Corps Air Station, Beaufort, S.C.

Two Babcock-Wilcox, 75 MBtu/hr. boilers

Distillate Fuel as a Primary Fuel

The Navy currently has three installations using distillate fuel as a fuel. These activities include:

Washington Navy Yard, D.C.

Two Edgemoor Iron Works, 184 MBtu/hr. boilers
One Springfield, 226 MBtu/hr. boiler

Puget Sound Naval Shipyard, Wa.

Four Babcock-Wilcox, 78 MBtu/hr. boilers

Naval Air Station, Alameda, Ca.

Three Keeler, 50 MBtu/hr. boilers

Natural Gas as a Primary Fuel.

Eleven naval installations currently use natural gas as a primary fuel. activities include:

Navy Public Works Center, Great Lakes, Ill.

Three Riley Stoker, 48 MBtu/hr. boilers
One Riley Stoker, 96 MBtu/hr. boilers
Two Combustion Engineering, 273 MBtu/hr. boilers

Marine Corps Recruit Depot, Parris Is., S.C.

Three Babcock-Wilcox, 65 MBtu/hr. boilers
One Riley Stoker, 65 MBtu/hr. boiler

- <u>Naval Air Station, Memphis, Tn.</u>

  Four Babcock-Wilcox, 63 MBtu/hr. boilers
  One Wickes, 123 MBtu/hr. boiler

- <u>Naval Air Station, Whiting Field, Fla.</u>

  One Murray Iron Works, 64 MBtu/hr. boiler

- <u>Navy Public Works Center, Pensacola, Fl.</u>

  Two Babcock-Wilcox, 125 MBtu/hr. boilers
  One Erie City Iron Works, 220 MBtu/hr. boiler

- <u>Naval Air Station, Corpus Christi, Tx.</u>

  Four Wickes, 63 MBtu/hr. boilers

- <u>Long Beach Naval Shipyard, Ca</u>

  Three Erie City, 81 MBtu/hr. boilers

- <u>Naval Air Station, Alameda, Ca.</u>

  Two Erie City, 100 MBtu/hr. boilers
  Two Babcock-Wilcox, 120 MBtu/hr. boilers

- <u>Naval Support Activity, Treasure Is., San Francisco, Ca.</u>

  Two Babcock-Wilcox, 75 MBtu/hr. boilers

- <u>Mare Island Naval Shipyard, Vallejo, Ca.</u>

  Two Keeler, 165 MBtu/hr. boilers
  One Combustion Engineering, 250 MBtu/hr. boiler

- <u>Naval Air Station, Whidbey Island, Wa.</u>

  One Wickes, 69 MBtu/hr. boiler

C.1.4 <u>Residual Oil Fired Being Converted to Coal.</u>

Six naval installations have either completed or are in the process of completing the conversion from residual oil to coal as a primary fuel. These activities include:

- <u>Marine Corps Development and Education Center, Quantico, Va.</u>

  Two Combustion Engineering, 61 MBtu/hr. boilers

One Riley Stoker, 67 MBtu/hr. boiler
One Riley Stoker, 146 MBtu/hr. boiler

- <u>Naval Ordnance Center, Indian Head, Md.</u>

  Three Combustion Engineering, 189 MBtu/hr. boilers

- <u>Naval Amphibious Base, Little Creek, Va.</u>

  Three Wickes, 100 MBtu/hr. boilers

- <u>Marine Corps Base, Camp LeJuene, N.C.</u>

  Four Riley Stoker, 114 MBtu/hr. boilers

- <u>Puget Sound Naval Shipyard, Bremerton, Wa.</u>

  The Puget Sound main boilers in Bldg. 106 are being replaced under MCON Project P500 with three new 150 MBtu/hr. coal-fired boilers with RDF capabilities.

- <u>Bremerton Sub Base, Bangor, Wa.</u>

  Two Keeler, 60 MBtu/hr. boilers

C.1.5 <u>Coal as a Primary Fuel</u>

The Navy currently has three activities using coal as a primary fuel. These activities include:

- <u>Navy Public Works Center, NAVBASE, Norfolk, Va.</u>

  One Riley, 220 MBtu/hr. boiler

- <u>Marine Corps Air Station, Cherry Pt., N.C.</u>

  Two Keeler, 95 MBtu/hr. boilers

- <u>Charleston Naval Shipyard, S.C.</u>

  Five Babcock-Wilcox, 60 MBtu/hr. boilers

C.1.6 <u>RDF as a Primary Fuel</u>

The following installation currently uses unprocessed RDF in a mass burning boiler plant facility:

- <u>Navy Public Works Center, NAVBASE, Norfolk, Va.</u>

  Two Foster-Wheeler, 75 MBtu/hr. boilers

C.2 TECHNICAL EVALUATION

Of the 149 active boilers listed with a rated capacity of 50 MBtu/hr. or greater, 119 are not recommended for consideration for conversion to co-fired RDF and fossil fuel for technical reasons. These boilers are summarized as follows:

Category	Inventory	Technically Unsuitable	Technically Suitable
Residual Oil-Fired	74	68	6
Distillate Fuel-fired	10	7	3
Natural Gas-fired	36	31	5
Residual Oil (Converted to coal-fired)	19	8	11
Coal-fired	8	5	3
RDF-fired	2	0	2
	149	119	30

C.2.1 Residual Oil-Fired Boilers

The following boilers are not considered to be suitable for conversion to co-fired RDF and oil, for the technical or operational reasons listed:

- Portsmouth Naval Shipyard, N.H.

  Three Edgemoor Iron Works, 150 MBtu/hr. boilers

  Note: Boilers are overaged.

  One Babcock-Wilcox, 185 MBtu/hr. boiler

  One Union Iron Works, 64 MBtu/hr. boiler

  Note: Commander, Portsmouth NSY ltr Ser 400/345 of 18 Nov 82 establishes that RDF cannot be fired at the shipyard for controlled industrial reasons.

- <u>Naval Education and Training Center, Newport, R.I.</u>

  One Keeler, 110 MBtu/hr. boiler

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements for RDF.

  One Babcock-Wilcox, 50 MBtu/hr. boiler

  Note: Package boiler - cannot be converted.

  Two Riley Stoker, 80 MBtu/hr. boilers

  One Babcock-Wilcox, 60 MBtu/hr. boilers

  Note: Boilers are overaged.

- <u>Naval Air Station, Brunswick, Me.</u>

  Four Babcock-Wilcox, 64-69 MBtu/hr. boilers

  Note: Boiler plant operates only 7 months during the year. In addition, boilers are being converted to wood chip burning units.

- <u>Naval Air Engineering Center, Lakehurst, N.J.</u>

  One Keeler, 55 MBtu/hr. boiler

  Note: Single unit. Requires a single unit to be on fossil fuel.

- <u>Philadelphia Naval Shipyard, Pa.</u>

  Four Combustion Engineering, 170 MBtu/hr. boilers

  Two Combustion Engineering, 162 MBtu/hr. boilers

  Note: Units are overaged. Philadelphia is currently developing a municipal solid waste boiler plant project to be run by the city to replace majority of the steam demand currently being supplied by the existing plant.

One Combustion Engineering, 170 MBtu/hr. boiler

Note: Would be the only unit to be converted. Not recommended. Majority of load will be provided by the proposed municipal RDF plant.

- <u>Allegany Ballistics Laboratory, Md.</u>

  Two Riley Stoker, 75 MBtu/hr. boilers

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements of RDF. Package units.

- <u>Naval Research Laboratory, Washington D.C.</u>

  Two Riley Stoker, 95 MBtu/hr. boilers

  Note: Boilers are being replaced; ref: C.O. NRL Washington ltr of 05 Jan 1983.

- <u>Naval Air Test Center, Patuxent River, Md.</u>

  Three International, 85 MBtu/hr. boilers

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements of RDF.

- <u>Naval Medical Center, Bethesda, Md.</u>

  Four Clever Brooks, 68 MBtu/hr. boilers

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements of RDF. Package units.

- <u>Norfolk Naval Shipyard, Portsmouth, Va.</u>

  Three Combustion Engineering, 150 MBtu/hr. boilers

  Three Riley Stoker, 150 MBtu/hr. boilers

  One Wickes, 85 MBtu/hr. boiler (Trailer mounted)

One Babcock-Wilcox, 233 MBtu/hr. boiler (Barge mounted)

Note: The six Combustion Engineering and Riley Stoker boilers are overaged. The Wickes boiler is trailer mounted. The Babcock-Wilcox boiler is barge mounted. The entire plant is planned to be replaced with an RDF/coal boiler plant to be operational in 1987 or 1988. Atlantic Div., NAVFACENGCOM is currently designing the proposed RDF plant.

- <u>Naval Air Station, Oceana, Va.</u>

  Two Union Iron Works, 80 MBtu/hr. boilers

  One Bigelow, 80 MBtu/hr. boiler

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements of RDF. Alternative would be to derate the boiler to 60% of capacity requiring the station to run all boilers during winter months. This would be unsatisfactory. In addition, spring, summer, fall (5 months) steam demand loads are very small.

- <u>Fleet Combat Directions Systems Training Center - Atlantic, Dam Neck, Virginia Beach, Va.</u>

  Two Trane-Murray, 50 MBtu/hr. boilers

  One Keeler, 50 MBtu/hr. boilers

  Note: All three units are package boilers and cannot be converted.

- <u>Navy Public Works Center, Naval Base, Norfolk, Va.</u>

  Three Riley Stoker, 94 MBtu/hr. boilers

  Three Combustion Engineering, 125 MBtu/hr. boilers

One Combustion Engineering, 144 MBtu/hr. boiler

Two Riley Stoker, 119 MBtu/hr. boilers

One Wickes, 75 MBtu/hr. boiler

Note: Boilers are overaged, the main plant is extremely congested and there is no room to install an ash removal system.

- <u>Marine Corps Air Station, Cherry Point, N.C.</u>

  One Edgemoor Iron Works, 40 MBtu/hr. boiler

  Two Wickes, 63 MBtu/hr. boilers

  Note: Boilers are overaged.

- <u>Marine Corps Base, Camp LeJuene, N.C.</u>

  One Trane, 100 MBtu/hr. boiler

  Three Trane, 53 MBtu/hr. boilers

  Two Combustion Engineering, 52 MBtu/hr. boilers

  Note: Units are package boilers

- <u>Marine Corps Air Station, Beaufort, S.C.</u>

  Two Babcock-Wilcox, 75 MBtu/hr. boilers

  Note: Inadequate combustion chamber to support volumetric heat release rate requirements of RDF. Boilers are also floor mounted, slab on grade. No capabilities to remove ash.

C.2.2 <u>Distillate Fuel-Fired Boilers</u>

The following boilers are not considered to be suitable for conversion to co-fired RDF and oil, for the technical reasons listed:

- <u>Washington Navy Yard, D.C.</u>

  Two Edgemoor Iron Works, 184 MBtu/hr. boilers

  Note: Boilers are overaged and ash hoppers have been removed.

One Springfield, 226 MBtu/hr. boiler.

Note: Boiler was modified with the removal of the ash hopper and reframing of the building under the main boiler combustion chamber. The plant has no capability, nor can it be altered, to remove large volumes of ash associated with RDF.

- Puget Sound Naval Shipyard, Wa.

Four Babcock-Wilcox, 78 MBtu/hr. boilers

Note: Boilers are overaged and are package units.

C.2.3 Natural Gas-Fired Boilers

The following natural gas-fired boilers are not considered to be suitable for conversion to co-fired RDF and oil, for the technical reasons listed:

- Navy Public Works Center, Great Lakes, Il.

Three Riley Stoker, 48 MBtu/hr. boilers

One Riley Stoker, 96 MBtu/hr. boiler

Note: Boilers are overaged. In addition, the three 48 MBtu/hr. boilers are operationally derated from 60 MBtu/hr. and are considered to be too small.

One Combustion Engineering, 273 MBtu/hr. boiler

Note: Unit is a package boiler.

- Marine Corps Recruit Depot, Parris Is., S.C.

Three Babcock-Wilcox, 65 MBtu/hr. boilers

Note: Boilers are overaged.

One Riley Stoker, 65 MBtu/hr. boiler

Note: Boiler is being replaced by a package boiler.

o <u>Naval Air Station, Memphis, Tn.</u>

Four Babcock-Wilcox, 63 MBtu/hr. boilers

Note: Boilers are overaged and are package units.

One Wickes, 123 MBtu/hr. boiler

Note: Boiler has inadequate combustion chamber to support the volumetric heat release rate requirements of RDF without extensive derating. This would require plant conversion to support RDF use in one boiler and is, therefore, not recommended.

o <u>Naval Air Station, Whiting Field, Fl.</u>

One Murray Iron Works, 64 MBtu/hr. boiler

Note: Boiler is a single unit. It also has inadequate combustion chamber volume to support volumetric heat release rate requirements of RDF. To produce volumetric heat release rate would require derating of boiler to a degree that capacity would be too small.

o <u>Navy Public Works Center, Pensacola, Fla.</u>

One Erie City Iron Works, 220 MBtu/hr. boiler

Note: Designed as a package boiler; use as backup for other two boilers

o <u>Naval Air Station, Corpus Christi, Tx.</u>

Four Wickes, 63 MBtu/hr. boilers

Note: Boilers are overaged and are package units.

o <u>Long Beach Naval Shipyard, Ca.</u>

Three Erie City, 81 MBtu/hr. boilers

Note: Units are package boilers

- <u>Naval Air Station, Alameda, Ca.</u>

  Two Erie City, 100 MBtu/hr. boilers

  Note: Units are package boilers.

  Two Babcock-Wilcox, 120 MBtu/hr. boilers

  Note: Boilers are overaged.

- <u>Naval Support Activity, Treasure Is., Ca.</u>

  Two Babcock-Wilcox, 75 MBtu/hr. boilers

  Note: There are inadequate numbers of boilers to be converted; i.e., one of two. Boilers are also floor mounted and do not have ash hoppers.

- <u>Mare Island Naval Shipyard, Vallejo, Ca.</u>

  One Combustion Engineering, 250 MBtu/hr. boiler.

  Note: Boiler is a package unit.

- <u>Naval Air Station, Whidbey Island, Wa.</u>

  One Wickes, 69 MBtu/hr. boiler

  Note: This is a single boiler required to be operated on fossil fuel, and it is not recommended for conversion.

C.2.4 <u>Coal-Fired Boilers</u>

The following coal-fired boilers are not considered to be suitable for conversion to co-fired RDF and coal, for the technical reasons listed:

- <u>Marine Corps Development and Education Center, Quantico, Va.</u>

  Two Combustion Engineering, 61 MBtu/hr. boilers

  One Riley Stoker, 67 MBtu/hr. boiler

  One Riley Stoker, 146 MBtu/hr. boiler

  Note: Boilers are overaged.

- o Marine Corps Base, Camp Lejuene, N.C.

  Four Riley Stoker, 114 MBtu/hr. boilers

  Note: Boilers are overaged.

- o Charleston Naval Shipyard, S.C.

  Five Babcock-Wilcox, 60 MBtu/hr. boilers

  Note: Boilers are overaged.

C.3 ECONOMIC EVALUATION

Of the 30 active boilers listed with a rated capacity of 50 MBtu/hr. or greater and having the technical characteristics considered suitable for co-firing RDF and oil, 6 appear to possess economic possibilities, 3 would have to be held in oil-fired standby status, 5 do not appear to have suitable payback potential, and 16 are coal-fired and are considered to be beyond the scope of this project. In summary:

Category	Inventory	Economic Possibility	Economically Unsuitable	Other Requirement
Residual oil-fired	6	4	0	2[3]
Distillate fuel-fired	3	2	0	1[4]
Natural gas-fired	5	0	5	0
Residual oil (converted to coal-fired)	11[1]	-	-	-
Coal-fired	3[1]	-	-	-
RDF-fired	2[2]	-	-	-
	30[1/2]	6	5	3[3/4]

Note:
1. Not evaluated under this project.
2. Does not require evaluation; already burning solid waste.
3. Two boilers would be required to be held in standby status as fossil fuel-fired boilers.
4. One boiler would be required to be held in standby.

C.3.1 Residual Oil-Fired Boilers

The following residual oil-fired boiler should not be considered for conversion:

- Navy Sub Base New London, Ct.

  One Keeler, 96 MBtu/hr. boiler

  One Babcock-Wilcox, 92 MBtu/hr. boiler

  Note: Required to be held in oil-fired standby status.

C.3.2 Distillate Fuel-Fired Boilers

The following distillate fuel-fired boilers should not be considered for conversion:

- Naval Air Station, Alameda, Ca.

  One Keeler, 50 MBtu/hr. boiler

  Note: Required to be held in fossil fuel-fired standby status.

C.3.3 Natural Gas-Fired Boilers

The following natural gas-fired boilers are not considered to have adequate economic payback to support conversion to co-fired RDF and oil:

- Navy Public Works Center, Great Lakes, Il.

  One Combustion Engineering, 273 MBtu/hr. boiler

  Note: The net loss would be in excess of $2 million per year to convert from natural gas at $4.40 per MBtu to 80% residual oil ($6.32 per MBtu) and 20% RDF ($1.35-2.70 per MBtu).

- Navy Public Works Center, Pensacola, Fl.

  Two Babcock-Wilcox, 125 MBtu/hr. boilers

  Note: The net loss would be in excess of $2 million per year.

- Mare Island Naval Shipyard, Vallejo, Ca.

  Two Keeler, 165 MBtu/hr. boilers

  Note: The net loss would be in excess of $0.5 million per year.

END

FILMED

8-83

DTIC